Master Planning

For

Quaid-E-Azam Solar Park

(Draft)

November, 2013

Contents

List of Attached Drawings

Chapter 1

INTRODUCTION

1.1 BACKGROUND

Pakistan is facing an acute energy crisis for the last many years. There is an urgent need to REDUCE the ever widening gap between demand and supply of electricity in the country. Punjab being the largest consumer of electricity in the country is worst hit in terms of quality of life and economic cost. The Government of Punjab is doing all it can to add additional power to the system thorugh alternative energy sources. Punjab has a vast potential for solar power generation. There is a keen investor interest in solar subsector, as indicated by entrepreneurs from various countries. The Punjab Government intends to develop Quaid-e-Azam Solar Park near Bahawallpur on a fast track basis to bring in investors as soon as possible.

The joint venture of Engineering Consultancy Services Punjab (Pvt) Ltd. (ECSP) and HydroChina Xibei Engieering Corporation, Republic of China have been engaged by the Energy Department, Government of the Punjab for preparing the Master Plan, Feasibility Study and PC-1 for Development of Infrastructure of the Quaid-e-Azam Solar Park.

Inception Report for the Project was submitted on 11 October, 2013. The Client's comments on the section of the Inception Report dealing with the Master Plan have been incorporated in the Draft Master Plan in hand.

1.2 SCOPE AND PLANNING BASIS

1.2.1 Planning Basis

The Consultants have utilized the following basic documents for developing the master plan :

1) International codes and standards related to photovoltaic solar power generation including those of the People’s Republic of China;

2) The Owner’s requirements and suggestions for the planning;

3) Report on Solar Interconnection by NTDC;

1.2.2 Scope of Planning

According to the Consultancy Services Contract signed with the Energy Department, Government of the Punjab, the development conditions at the proposed site, such as the solar resource, topography, geology, transportation, municipal facilities, electricity for construction, grid connection etc., have been kept in view for planning of this grid-connected photovoltaic solar power generation park

The road network, power supply lines, water supply, drainage and grid connection have been planned and designed keeping in view the design concept of grid-connected photovoltaic solar power park.

The geographic location , terrain geology, available resources, power transmission grid etc., of the site have also been given due consideration in planning. The project area has been divided into various blocks based on state-of-the-art approach of the grid-connected photovoltaic power plant, developer's tendencies and the major equipment models available for selection, so that the land and solar energy resources can be utilized rationally and efficiently to achieve the most appropriate layout, focused implementation and optimum development.

The available area for the solar park is about 5.69 km wide from east to west, and about 8.17 km long from north to south, covering an area of about 40.5 km^2. The land of the project area is owned by the government. The solar park area is planned to generate a total of 1,000 MW in three phases: Phase-I for 100MWp, Phase-II for 300MWp, and Phase-III for 600 MWp. Refer drawing No.1 for Site location map of Quaid-e-Azam Solar Park.

1.3 PLANNING GUIDELINES AND PRINCIPLES

1.3.1 Planning Guidelines

With the objective of building a new resource-saving and environment-friendly large-scale solar energy park, the Consultants have used latest international and domestic concepts, methods and techniques, keeping in view the natural topography and climatic conditions of the project area. The proposed plan is based on the constraints of specific environmental resources and the principle of "rational layout, environmental protection and development" by utilizing appropriate technology.

1.3.2 Planning Principles

The following principles have been followed for planning of the QA solar park;

1) Environment-oriented and eco-friendly development, based on protecting and strengthening the ecological status by maintaining harmony between the natural environment and renewable clean

energy power plants for building a sustainable solar energy park.

2) Economical and intensive use of land, by focusing on the harmony between the public facilities in the park and the blocks allocated for solar farms to develop a compact solar park, having facilities such as roads, water supply, electricity and other related infrastructure.

3) Planning solar park area, in a new development mode of centralized, large-scale and efficient power generation facility keeping in view the local conditions.

1.4 **Objectives**

The planning of Quaid-E-Azam Solar Park is based on a combination of multiple solar farms, one-step construction, and simultaneous development, with centralized mode, for vigorously promoting solar energy as an alternative power source in the country.

Infrastructure facilities, such as public roads and accesses, electricity transmission corridors, water supply network, grid station etc., are required to ensure ecological protection, and maintain harmony between the solar park and the environment, as well as to meet the requirements of synchronized construction and implementation by a number of developers.

Chapter 2

ANALYSIS OF THE CONSTRUCTION CONDITIONS

2.1 GEOGRAPHIC CONDITIONS

Punjab province of Pakistan covers an area of 205,334 km^2 and is Pakistan's second largest province in terms of area. It is located on the northwestern edge of the Indian plate. Most parts of the province are fertile river valleys, with deserts in the eastern and the western parts, and sub-systems of Himalayan Mountains in the north. Bahawalpur District is located in southern Punjab, with a total area of 24,830 km^2. About two-thirds of the territory of the district is covered by Cholistan desert.

The project area is located about 18km southeast of Bahawalpur, Punjab, having desert landscape, with ground elevations ranging from119m to 130m.

2.1.2 CLIMATIC CONDITIONS

Pakistan is located in the temperate zone, with subtropical arid and semi-arid climate. The climate is relatively hot and dry in general. Pakistan receives monsoon rainfall in summer and in winter receives rainfall due to western systems. Most of the country is arid to semi-arid except southern slopes of Himalayas and Sub-mountain region where the annual rainfall ranges from 760 mm to 2000 mm. The Balochistan province is the driest part which receives 210 mm on the average. Three-fourth part of the country receives rainfall less than 250 mm and 20% of it receives 125 mm. The hottest season is in June and July. The temperature for most areas at noon exceeds 40℃, or even more than 50℃.

Pakistan has cold winters, from the December to February, hot and dry springs from March to May, rainy summers from June to September with northwest monsoon climate and the monsoon declining season from October to December. But the seasons vary as geographical conditions change.

Pakistan is exposed to strong solar radiation, long hours of sunshine, and abundant solar energy resources. The annual sunshine hours are up to 2900h - 3300h, and the average daily sunshine hours are 8.1h - 9.2h.

2.2 RESOURCE CONDITIONS

2.2.1 Solar Energy Resources

With abundant solar energy resources in Pakistan, the total radiation amount of solar energy per year is 6,100 MJ/m^2 and the annual theoretical storage amount is more than 2,900,000,000 kWh. Development and utilization of solar energy therefore, has a bright future in the country. Total solar radiation is maximum in summer and minimum in winter. The northern region and southern coastal regions however, are exposed to lower intensities of solar radiation than the central and western regions. The annual sunshine hours are 2,900h to 3,300h. As such, Pakistan can easily harness solar energy on a large scale.

Punjab Province is located within the mid-latitude zone, where the solar radiation intensity is high, illumination time is long, and total annual radiation quantity is 6,100 MJ/m^2 to 7,200 MJ/m^2. Out of this, the direct radiation amount accounts for over 60% of the total radiation amount, and the value is second only to that of Balochistan and Sindh Province. From the Distribution Diagram for Total Radiation Space Changes in Pakistan (see Fig 2.1), it is evident that the space distribution is characterized by south-to-north decrease.

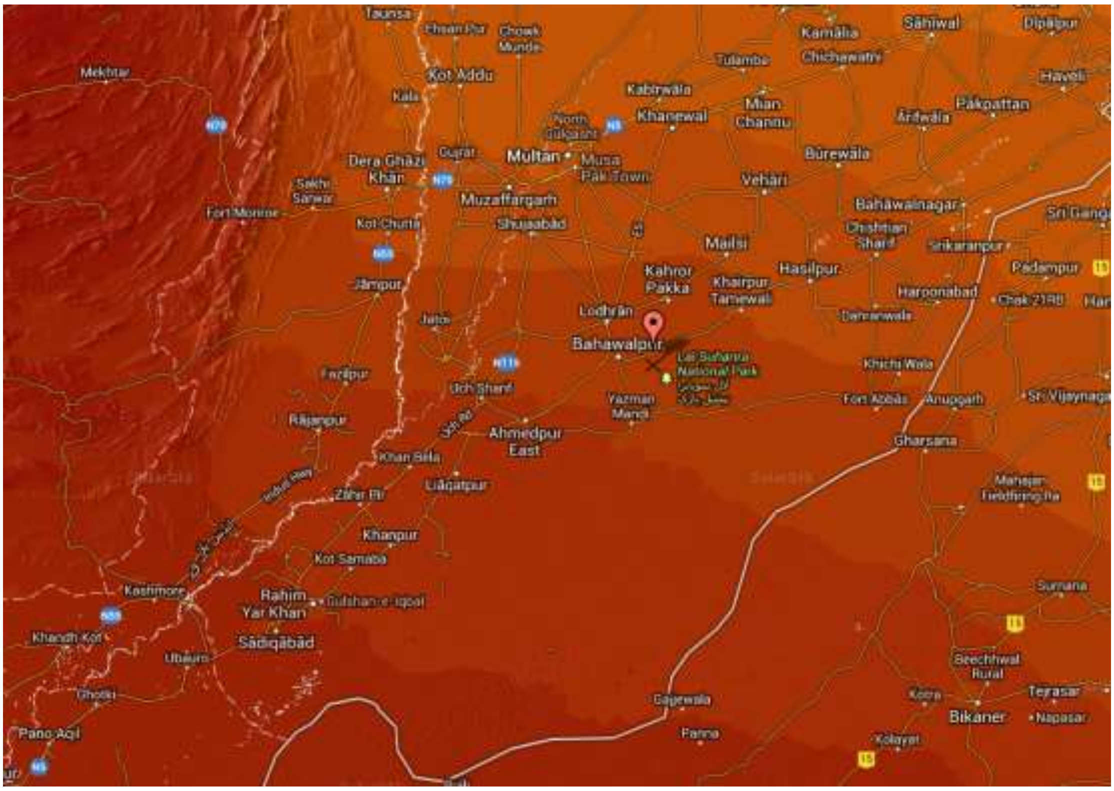


Fig. 2.1 Radiation Distribution in Punjab Province

2.2.1.1 Meteorological Data of Bahawalpur

Bahawalpur District is located in the south of Punjab Province. The Meteorological Station in Bahawalpur District is located at 71.78 degrees east longitude and 29.4 degrees north latitude (in terms of the geographical coordinates), and the Observation Field is 116m above the sea level. The basic available meteorological data and the sunshine hours from 1982 to 1991 and from 1996 to 2012 (27 years) of this Meteorological Station have been collected.

According to the actual meteorological data, statistics have been worked out for major meteorological factors as shown in Table 2.1.

Table 2.1 Statistics of Major Meteorological Factors at Bahawalpur Meteorological Station

No.	Item	Value	Remarks
1	Annual average temperature (℃)	25.6	
2	Annual extreme maximum temperature (℃)	50	June, 1992
3	Annual average rainfall (mm)	201.1	
4	Annual rainstorms	10	August, 2006
5	Annual average wind speed (m/s)	2.3	8:00 AM

2.2.1.2 Analysis of Solar Energy Resources

1) Interannual variation analysis for sunshine hours

In order to effectively determine the variation trend of the amount of annual total solar radiation and to facilitate the data analysis, the variation diagram of sunshine hours in this region has been developed on the basis of the sunshine hours from 1982 to 1991 and from 1996 to 2012 as shown in Fig. 2.2.

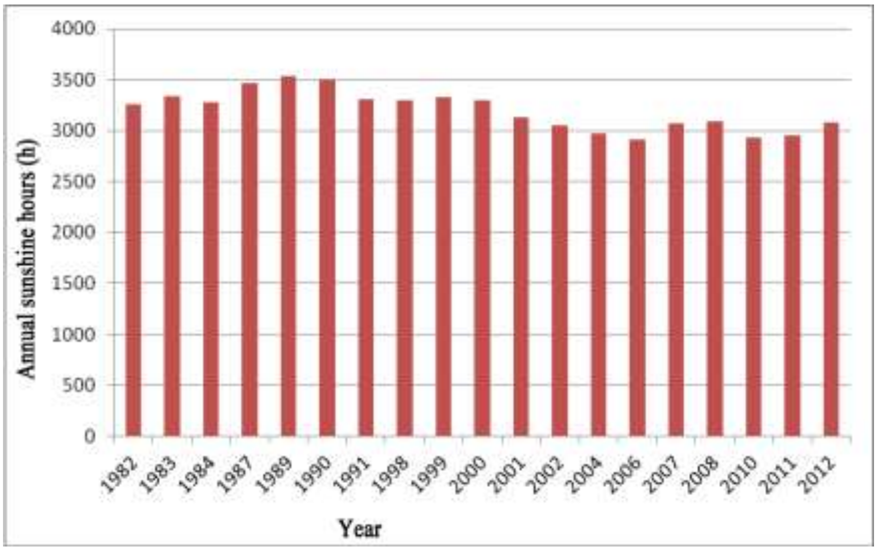


Fig. 2.2 Variation Diagram of Annual Sunshine Hours

From Fig. 2.2, it can be seen that the sunshine hours in Bahawalpur district have actually varied very little over the years and the value has remained between 2,900 h to 3,300 h. The annual average sunshine hours are 3,201 h.

2) Inter-monthly variation analysis for total solar radiation

The solar radiation and sunshine hours in the project area have been obtained by using the meteorological data website of National Aeronautics and Space Administration (NASA), as well as by Meteonorm software as shown in Figs. 2.3, 2.4, 2.5 and 2.6.

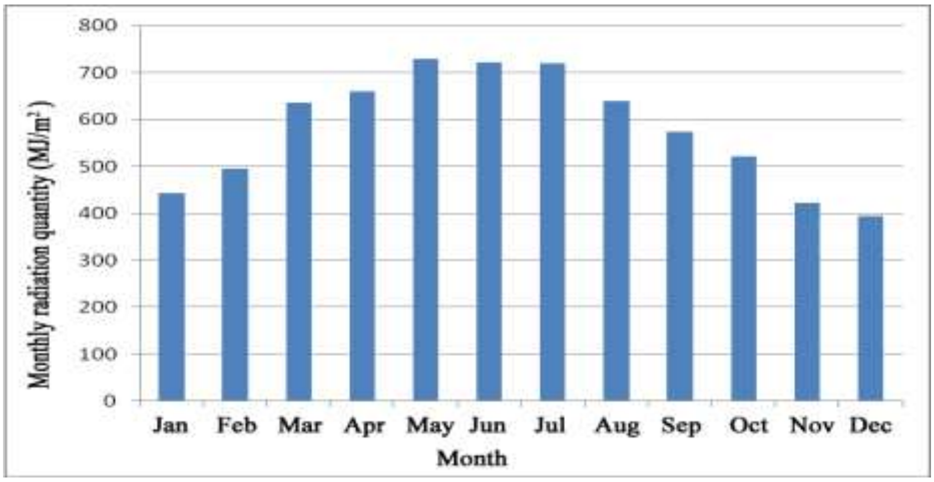


Fig. 2.3 Monthly Average Solar Radiation Quantity in 22 Years from NASA (MJ/m^2)

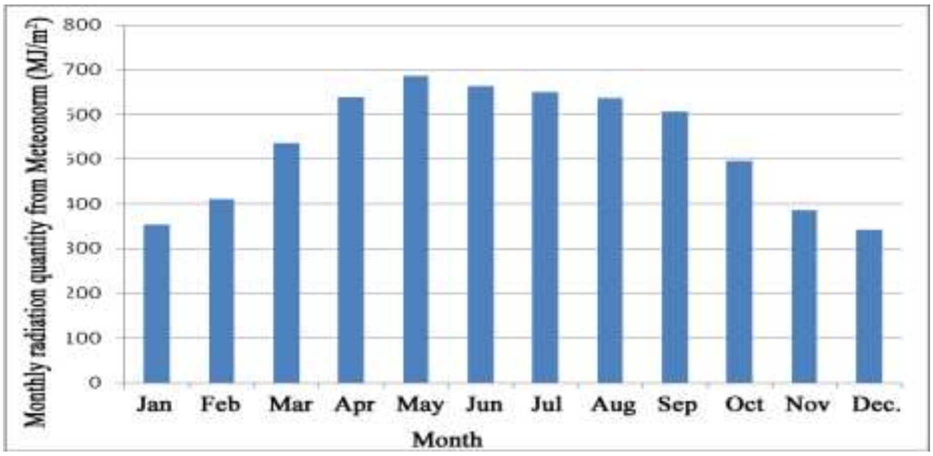


Fig. 2.4 Monthly Average Solar Radiation from Meteonorm (MJ/m^2)

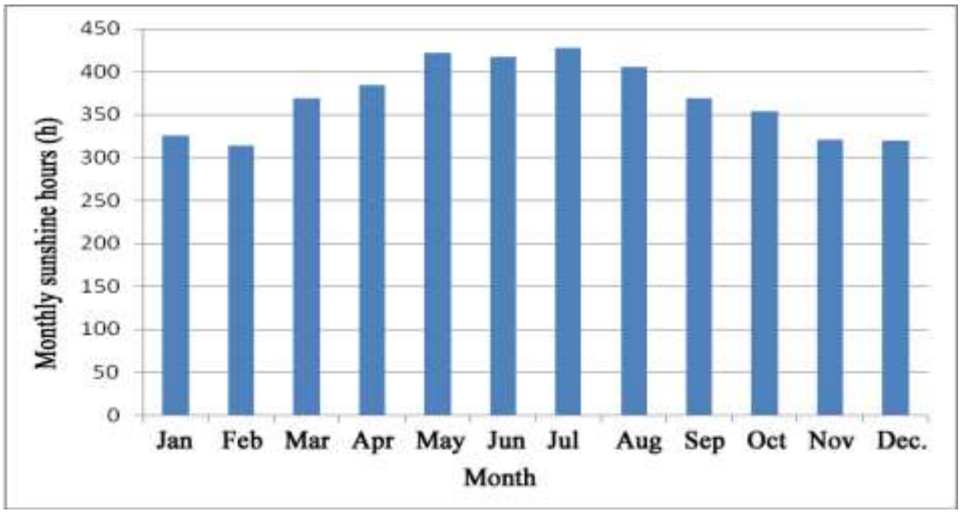


Fig. 2.5 Monthly Average Sunshine Hours in 22 Years from NASA (h)

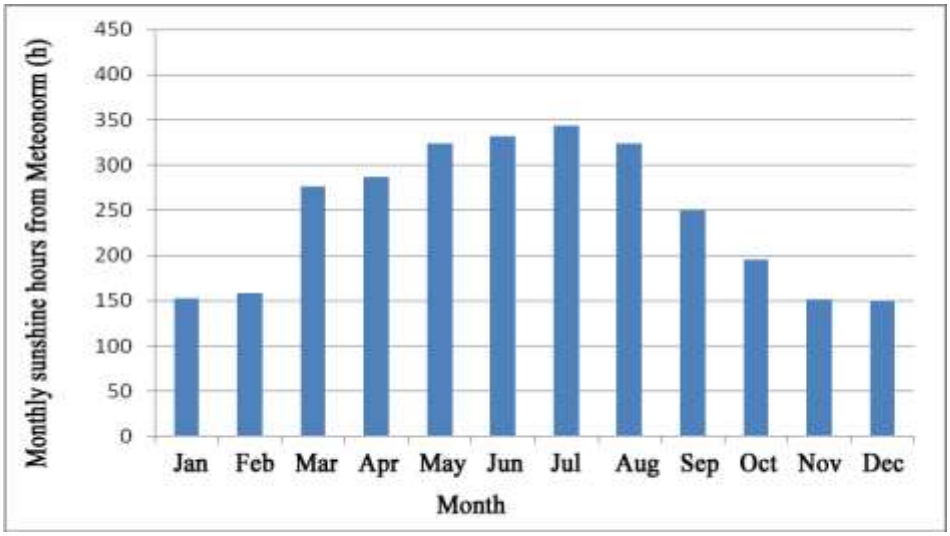


Fig. 2.6 Monthly Average Sunshine Hours from Meteonorm (h)

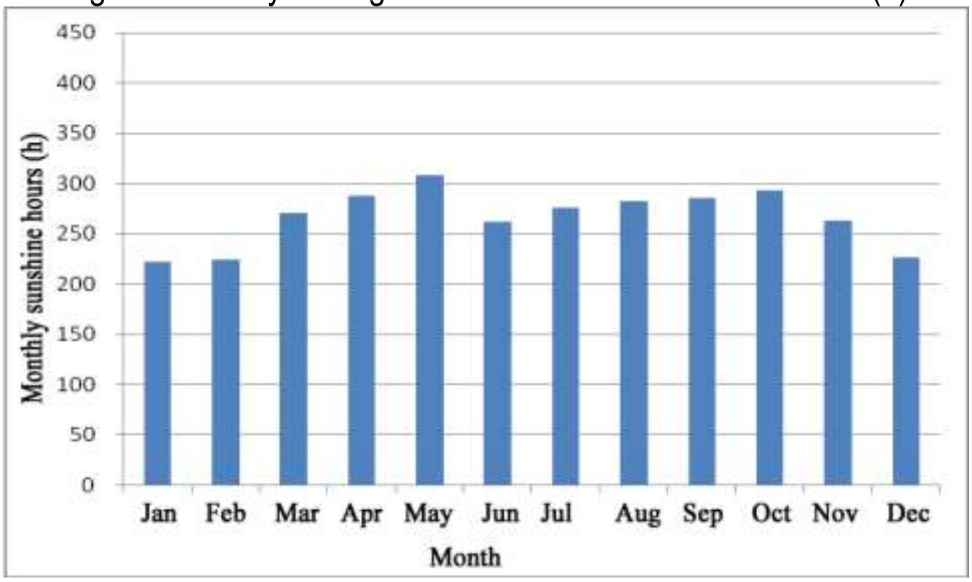


Fig. 2.7 Annual Average Sunshine Hours Actually Measured in Bahawalpur District (h)

Figs. 2.5, 2.6 and 2.7, show that the inter-monthly variation is huge for sunshine hours in this area. The annual average sunshine hours are 4,427.2 and 2,946 respectively obtained through NASA website and Meteonorm software, while the actual measured hours in this area are 3,201. The value obtained from NASA's website is obviously much higher than the actual measured value while the data obtained by using the Meteonorm software is close to the actual measured value. Since limited data is available, it cannot be used for calculating the local radiation amount. Therefore, the data obtained by using Meteonorm software has been used as the basis of the study at this stage.

Accordingly, it is determined that for QA Solar Park , the total solar radiation amount is 6,408MJ/m^2 and the annual sunshine hours are 3,201.

Table 2.2 Solar Radiation Data

Month	January	February	March	April	May	June
Monthly standard radiation quantity (MJ/m^2)	354	411	536	638	686	664
Monthly standard sunshine hours	223	224	271	288	308	262
Month	July	August	September	October	November	December
Monthly standard radiation quantity (MJ/m^2)	651	637	606	496	386	343
Monthly standard sunshine hours	276	282	285	293	263	226

2.2.1.3 Comments on Solar Energy Resources

The radiation at the Project Site cannot be calculated directly because the only data that is available is of local sunshine hours and no radiation data is available in the vicinity of the project site. By analysis of data and comparison of results obtained thourgh NASA's website and Meteonorm software, it is concluded that at this stage, total radiation can be taken as 6,408MJ/$m^{2,}$ with the annual sunshine hours being 3,201. As such, the project area is considered to have abundant solar energy resource.

2.2.2 **Water Resources:**

Being in the arid zone, Bahawallpur district has very little rainfall, the annual rainfall being 200 to 250 mm. The ony local source of water in its desert area is local ponds where rain water is collected. Ground water is available in the northern part of the district but it is mostly brackish. Irrigation Canal namely Bahawal canal, Ahmadpur East Branch and Desret Branch irrigate in the northern part of the district. Due to seepage from these canals, sweet ground water aquifer is available along the canals.

2.2.3 **Energy Resources**

Pakistan has a vast mountainous region. The crustal movements in the history are obvious and geological activity is frequent. Furthermore, Pakistan is abundant in mineral resources. Coal reserves with Class A lignite as the main reserve, is approximately 185 billion tons and is distributed mainly in Sindh Province. The reserves of copper ore, iron ore, aluminum are 500 million tons, 600 million tons and 74 million tons respectively. In addition, there are large amounts of chromite, limestone, sandstone, dolomite, marble, precious stones, mineral salts and silica sand etc.

There is a lot of gas but little oil in Pakistan. The gas and oil resources are mainly distributed in the northern Pothowar region, southern Indus River basin and offshore continental shelf. The total reserve of natural gas is estimated to be 7,984,800 million m^3. The proved exploitable reserve of natural gas is 1,491,400 million m^3, among which 537,700 million m^3 has been exploited. The total reserves of oil are 27 billion barrels. The proved reserves are 883 million barrels, among which 559 million barrels have been exploited. Currently, the energy consumption structure is seriously out-of-balance. The inter-dependency of petroleum and natural gas products is over 79% and the annual demand shall increase at the rate of 5.7% and 7.5% respectively for petroleum and natural gas products. In order to meet the increasing energy demand, Pakistan Government has to use a large amount of foreign currencies to import crude oil and petroleum products. In recent years, the high prices of petroleum and natural gas in the international market have resulted in huge pressure on national finance and national economy.

Pakistan's hydropower reserves are about 46 thousand MW, out of which only 14% have been developed (about 6500 MW). Pakistan has a huge potential for wind energy along the 1,046 km coastline of Sindh which is about 50 thousand MW. So far only Turkish Zorlu wind farm has been built with an installed capacity of 6MW. There are rich solar energy resources in most parts of the country, especially in Sindh, Balochistan and southern Punjab province, where annual sunshine hours are more than 3,000 and solar radiation received is about 2,000 kWh/m^2. Although the intensity of sunlight is strong in these areas, harnessing this energy is still a challenge in the development of solar energy due to lack of large-scale energy systems.

2.2.4 **Land Resources**

The total area of Bahawalpur district is 24830 km^2, and about 2/3 of its area is covered by Cholistan Desert which is mostly barren. As such, during the development of large-scale grid photovoltaic solar park, no significant problems like resettlement are expected to be faced.

2.3 DEVELOPMENT CONDITIONS

2.3.1 Policy of GoPunjab

Government of the Punjab is encouraging investment in solar power generation for which the following incentives are available to prospective investors:

1) General Incentives

- ✧ Mandatory purchase of power generated by IPPs.
- ✧ The power purchase will ensure grid connection, off-take voltage and interface.
- ✧ Wheeling is allowed for renewable energy producers.
- ✧ Bonus incentive will be given on power production more than the bench mark level.
- ✧ NEPRA (National Electric Power Regulatory Authority) is in the process of announcing FIT (Feed in Tariff) soon.

2) Fiscal & Financial Incentives

- ✧ 17% Return of Equity assured for Solar Power Projects.
- ✧ No custom duty or sales tax on machinery, equipment and spares.
- ✧ Exemption on income tax including turnover rate tax and withholding tax on import.
- ✧ Repatriation of equity along with dividends freely allowed.
- ✧ Non-Muslims and non-residents exempted from payment of zakat on dividend paid by the company.

- Power generation companies can issue corporate registered bonds and shares at discounted prices.
- Foreign banks can underwrite shares and bonds issued by private power companies.
- Non-residents can purchase securities issued by Pakistani companies.
- Abolition of 5% limit on investment of equity in associated undertakings.
- Independent rating agencies are operating in Pakistan to facilitate investors in making informed decisions.
- Government of Pakistan will guarantee the term of executed agreements including payment terms.
- Sovereign Guarantee by the Federal Government.

2.3.2 Topographic Survey:

2.3.2.1 Boundary Demarcation:

Total land allocated for Quaid-e-Azam Solar Park is 10,000 acres. However for present development project, 6,350 acres in the northern part of the allocated land has been considered sufficient. The remaining land will be used for extension works at a later stage. Boundary corners were physically identified and handed over by the Revenue Department field staff to our staff progressively. A total of twenty boundary corners were located on-site jointly with the revenue staff. Wooden pegs were installed at each corner as markers. The approximate coordinates of boundary pegs were initially surveyed by hand-held GPS for general location plan and subsequently, after establishment of survey control network were surveyed by dual frequency GPS.

The approximate and exact coordinates of boundary corner pegs were used by design engineers for layout of the infrastructure. Later on the boundary pegs were replaced by permanent concrete pillars. A typical boundary corner pillar is a PVC pipe 1500mm long and 100mm in diameter filled with concrete (1:2:4) ratios and has a steel nail at the center. The steel nail represents the corner location. The concrete pillar protrudes about 500mm above ground and is back filled with 1:4:8 PCC. The boundary corner number is painted on the side of the pillar.

Summary of boundary corner pillars along with UTM coordinates in WGS-84 datum is shown in table - 2.3. The figure 2.8 below shows boundary of the project area.

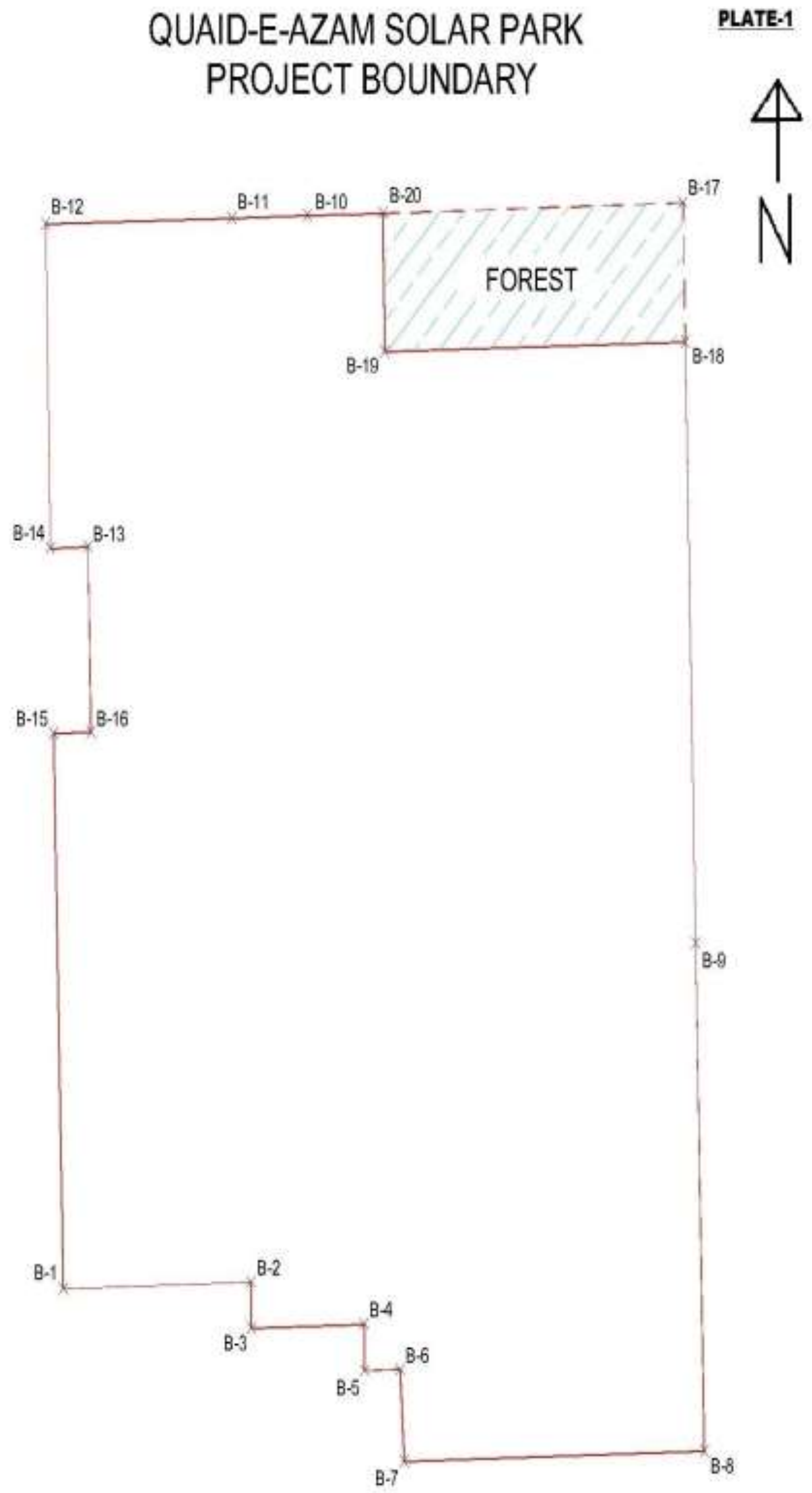


Figure 2.8

Table-2.3

SUMMARY OF BOUNDARY CORNER PILLARS

Boundary Corner No.	**UTM Coordinates in WGS-84 Datum**		**Remarks**
	Easting (m)	**Northing (m)**	
B-1	770975.14	3241382.43	Concrete Pillar
B-2	772652.32	3241425.64	Concrete Pillar
B-3	772658.03	3241124.84	Concrete Pillar
B-4	773662.38	3241151.75	Concrete Pillar
B-5	773670.31	3240849.57	Concrete Pillar
B-6	773986.33	3240857.02	Concrete Pillar
B-7	774023.47	3240256.88	Concrete Pillar
B-8	776706.08	3240324.95	Concrete Pillar
B-9	776625.34	3243635.90	Concrete Pillar
B-10	773159.34	3248375.81	Concrete Pillar
B-11	772484.64	3248357.93	Concrete Pillar
B-12	770818.31	3248320.43	Concrete Pillar
B-13	771196.92	3246218.94	Concrete Pillar
B-14	770860.90	3246207.22	Concrete Pillar
B-15	770889.88	3245002.69	Concrete Pillar
B-16	771225.22	3245008.76	Concrete Pillar
B-17	776510.88	3248459.82	Concrete Pillar
B-18	776532.14	3247550.36	Concrete Pillar
B-19	773850.19	3247488.22	Concrete Pillar
B-20	773830.93	3248390.21	Concrete Pillar

2.3.2.2 Establishment of Survey Control Network

The survey control network was established at site for carrying out topographic survey as described below;

Reference Datum

For elevations of project site, Survey of Pakistan (SOP) SBM situated in compound of Canal Rest House Asrani, on Bahawalpur - Hasilpur road is our reference datum. The coordinates of Asrani SBM are not available in record provided by SOP. Therefore the horizontal control of the reference control points for project site was established in WGS-84 by using Trimble 5800 dual frequency GPS. The survey control point, which has been used as reference control point for the survey of Quaid-e-Azam

Solar Park, Cholistan is appended below in Table-2.4:

Table 2.4

SURVEY CONTROL POINT

SOP BM No.	Coordinates in WGS-84		Elevation in National Datum (m)	Remarks
	Easting (m)	Northing (m)		
Asrani SBM	803,882.317	3,269,712.08	132.131	Situated in compound of Canal Rest House Asrani

2.3.2.3 Survey Methodology:

Data on survey control points of the topographic map for the park is to be surveyed and collected, the reference elevation datum shall be SOP national datum. Accordingly, the topographic maps (1:1000 in scale) for the park have been prepared. The area surveyed has been extended beyond the park development boundary by 30m.

The survey of the area has been carried out on the basis of the following criteria;

1. The surveying operation has been executed based on the survey code and the control network for the surveying operation of the park has been established;
2. The coordinate system is based on WGS-84 system;
3. The elevation system applies the national elevation datum of Pakistan;
4. The basic contour interval shall be 0.5m;
5. The basic surveying precision and the topographic map graphics satisfy the international practice of survey, and graphic

identifications are available;

6. Topography and landform both underground or ground such as river (lake), village, road (including width, etc), access, path, transmission line route, optic fiber cable for communications, canal, etc have been identified and marked out. Route directions of roads, transmission line and pipeline, etc beyond the park boundary but around the park has been marked out additionally;

7. Objects and topography, within the surveyed area, such as tombs, step terrace (outline each step shall be marked out) and wood scope, etc, have been identified and marked out; (important)

8. Gullies in the development park provided the height difference between the gulley bottom and the ground surface around the gulley is greater than 0.5m, has been marked out with the gulley outline. The contour lines are not interrupted by these marks.

9. High structures, objects (such as electric poles, mountain, hills, etc) within the range of 100m from the park which may affect the solar park development have been marked out with their locations and heights as well;

10. After survey completion, piers (concrete markers) for control points has been provided within the development park or at the park boundary handed over by Revenue Department staff; the number of the control points satisfies relevant requirements and identification of the control points are available. These control points are the benchmark control points for the construction survey operation.

Topographic survey of the area is shown in drawings number 2.

2.3.3 Geotechnical Investigations:

2.3.3.1 Seismic Potential

According to Building Code of Pakistan, zone 2A has been assigned to Bahawalpur City. For zone 2A, the seismic peak horizontal ground acceleration in the park area ranges from 0.08 - 0.16 g and the corresponding basic seismic intensity is category VI, belonging to a stable structure area.

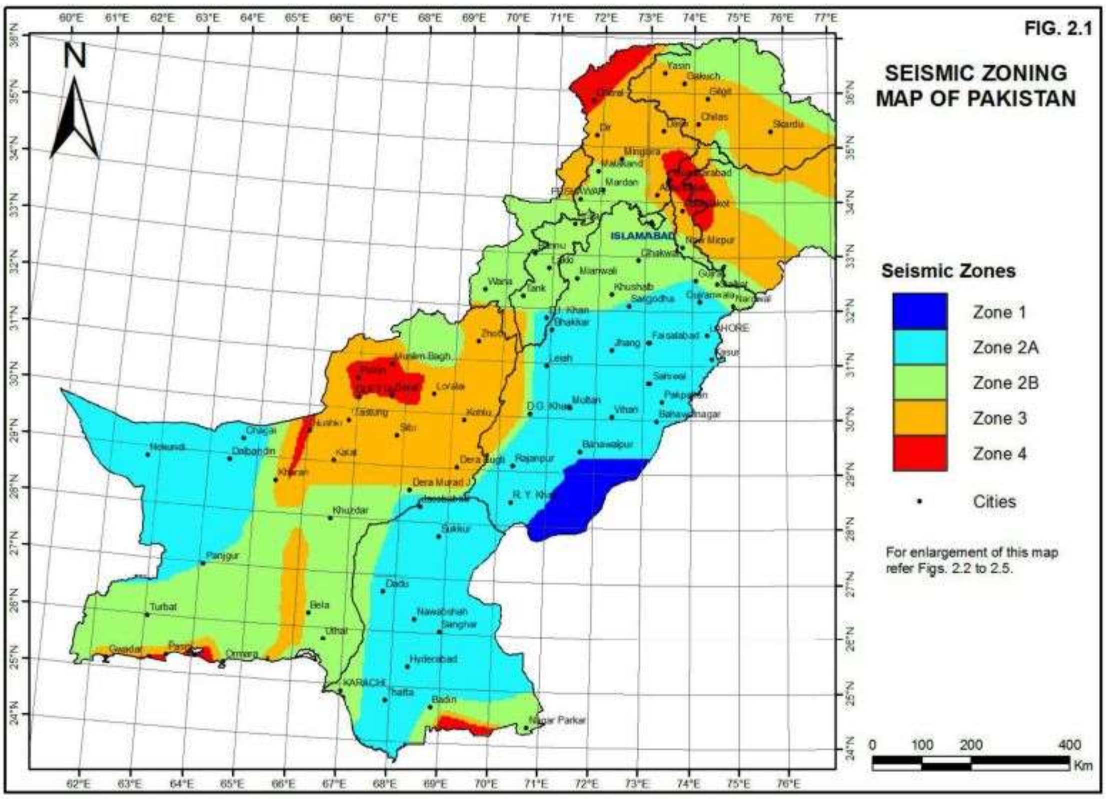


Fig. 2.9 Seismic zones map of Pakistan

2.3.3.2 Geology & Geotechnical Condition

1) Geographic and geomorphic conditions

Geomorphological, the project area is a desert, with flat geography and slight undulations, forming an alternative geomorphology of low dunes and depressions. The ground level is varying from 119m-130m, with a maximum height difference of 11m. Gullies are not properly developed in the area and sparse vegetation exists on the ground.

2) Formation lithology

The geotechnical investigations carried out in project area through augerholes and test pits have revealed that subsurface stratum is mainly class IV which comprises silty fine sand, silty clay and medium dense sand as its lithology. Details are as follows,

The layer ①-1: Holocene proluvial of the fourth system (Q_4) is a silty sand layer, grayish yellow, dry, loose to slightly dense, it is distributed on the desert surface; its thickness at the bottom layer is 1m – 3m.

The layer ①-2: Holocene proluvial of the fourth system (Q_4) is a silty sand layer, grayish yellow, dry, intermediate dense-dense, it is distributed under layer ①-1 of desert, its thickness under the top layer is 1m – 3m.

The layer ②: Holocene proluvial of the fourth system (Q4) is a silty clay layer, grayish yellow, dry, plastic-stiff-plastic, placed in the silty sand of the layer ① with a wide distribution at low areas of the Geography.

3) Hydrogeology

During these investigations, the ground water table was encountered in some auger holes in the northern part at a depth ranging from 7-8m below the existing ground level with brackish water prevailing, direction of groundwater flow being NE-SW.

4) Unfavorable physical and geological phenomena

Landslide, collapse, debris flow were not observed in the project area and no moving sand dunes exist.

2.3.3.3 Recommended Values for Physical Parameters of Foundation

For evaluation of allowable load carrying capacity, the design parameters have been selected on the basis of field and laboratory test results, technical literature and engineering judgment. The recommended design parameters are summarized below:

Table 2.5 Recommended Values for Physical and Mechanical Parameters of Foundation Soil

Soil Layer No.	Name of Rock & Soil	Status	Gravity Density (Natural) (kN/m^3)	Void ratio e	Compression Coefficient (MPa-1)	Compression Modulus (MPa)	Cohesion (kPa)	Frictional Angle (o)	Characteristic Value of Bearing Capacity fak (kPa)
①-1	Silty fine sand	Loose-slightly dense	16-17	0.8	0.3-0.4	10	0	25	130-150
①-2	Silty fine sand	Intermediate dense-dense	18-19	0.7	0.1-0.3	15	0	28	150-180
②	Silty clay	Plastic-stiff-plastic	17-18	0.8	0.3-0.5	8	18	20	120-130

A carefull record of all the material encountered and data of SPT's conducted in each borehole has been maintained in the form of Linear Sub-surface Profiles. The Sub-surface Profiles are appended to this report as Appendix-A

2.3.3.4 Main Geotechnical Problems and Evaluation on Site

1) Hierarchies for foundation on site

As per *Code for Investigation of Geotechnical Engineering* (GB50021-2001), site hierarchies, foundation level, and environment types shall be judged as follows:

A. According to the size and characteristics of engineering, as well as engineering damages or results affecting normal use caused by rock engineering problems, the engineering importance grades shall be divided into two levels. For general engineering, serious consequences might be caused;

B. Basic earthquake intensity on site is less than Grade VI, the geographic and geomorphic condition is simple, no impacts for underground water exist on the engineering, and the site is intermediately complicated;

C. According to the complexity of foundation, the foundation soil can be divided into seasonal frozen soil and particular soil, with foundation complexity as Grade II, i.e. moderately complex foundation;

D. (1), (2), (3) indicate that the level for engineering exploration is Grade II;

E. Project area belongs to arid areas, with larger groundwater buried depth; the foundation soil is strongly permeable layer; site environment categories are Class Ⅲ.

F. Project area is flat and wide, with loose sand (i.e. weak soil) as the foundation soil; equivalent shear wave velocity of stratum is less than 140 m/s; site area belongs to unfavorable location of constructive seismic area, with site category for Class Ⅳ.

2) Corrosivity of soil and groundwater (Chemical Aggressivity)

The chemical tests carried out on soil samples and groundwater indicate negligible concentration of sulphates in the sub-soil at the project site as per ACI 318. Concrete mix design should follow the guidelines of ACI 318 accordingly.

3) Vibration liquefaction evaluation

Basic earthquake intensity is less than grade Ⅵ on site; lithology is mainly the fine sand, soil perennially exists in dry state, and the buried depth of groundwater is relatively large, having no conditions for sand soil liquefaction. Therefore, no vibration liquefaction problems exist in geotechnical engineering.

4) Foundation soil resistivity

According to the engineering geological analogy, earth resistivity of fine sand layer favors 50Ω m-250Ω m.

5) The geological conditions and evaluation of foundation soil

The Project site is located in desert area and has a flat terrain. The lithologic character is silty-fine sand mingle with silty clay. The upper surface part ①-1 is silty-fine sand layer and the structure varies from loose to medium dense, with low bearing capacity. The geologic property of the surface works is poor, so it is suggested to carry out foundation treatment and pile foundation. The lower ①-2 silty-fine sand layer can be used as the bearing layer for the pile foundation.

The landform of the site area is flat, and there are no geological phenomenons like landslides, debris flow and so on. As such, it is suitable for the photovoltaic power project. But, as for low-lying areas, the adverse effects of seasonal floods shall be taken into consideration.

2.3.3.5 Evaluation of the stability and uniformity of the site

The basic seismic intensity of the site area is less than grade VI, so the site area is in a region of stable structure. The lithologic character is silty-fine sand present in large thickness, loose upper area and dense lower area, so the mechanical property is relatively low. The site type is class IV and soft soil mainly exists in the site area.

The landform of the site is flat and the water content in the soil and earth body is scarce. It is not equipped with the conditions of sand liquefaction, so the building of the site area is not much affected by underground water.

Above all, the site area has a stable structure. Uniformity and stability of the foundation soil is relatively sound, which is appropriate for constructing photovoltaic power plant.

2.3.3.6 Construction Materials

Main materials necessary for the project construction include sand, aggregates, cement, steel, wood, oil and etc. Adequate building material sources are available in vicinity of the project area; sand and aggregates can be bought from the nearby areas; while cement, steel and other building materials and supplies can be purchased from Bahawalpur. For power supply during construction, temporary connection can be obtained from WAPDA, while water required during construction can be obtained from a bore within the project area provided sweet water is available. Alternatively, it can be obtained from the existing tubewells along Ahmadpur canal or other nearby sources through bowsers.

2.3.3.7 Conclusions and suggestions

1) The seismic peak horizontal ground acceleration in the site area ranges from 0.08 - 0.16 g, and the corresponding basic seismic intensity is less than Grade VI, belonging to stable structure area.

2) The level of the project importance, site complexity and the foundation are Grade II, the project investigation grade is B.

3) The stratum of the site area is mainly quaternary strata, the lithologic character is silty-fine sand, with heavy thickness, and the strata varies from loose to dense. The natural state layer can not work as a foundation bearing layer, so it is suggested to carry out pile foundation. The lower ①-2 silty-fine sand layer can be used as the bearing layer of pile foundation.

It is suggested to carry out detailed geological investigations for the project, to further find out the composition, compaction degree, physical and mechanical property of the foundation soil of the project site.

2.3.4 Socio-economic situation and the development planning

2.3.4.1 Punjab

There are 35 districts in Punjab. In 2012, the population is 91.37 million, 99% persons being Muslims. Other religions are Christianity, Hinduism and Sikhism. The main races are Punjabis, Sindhis, the rest are Mahajirs, Baluchis and Pushtuns, Kashmir and etc.

The best developed industry and agriculture of Pakistan is in Punjab. The main industries include textile, sports goods, medical equipment, electrical appliances, machinery, bicycle, rickshaws, metal products, floor and food processing; the agriculture mainly includes wheat, cotton and rice; the mining industry includes coal, salt, gypsum, dolomite and sand.

The economy of Punjab is mainly based on agriculture and related industry. The total agricultural area is 12.23 million hectares and 490,000 hectares are forests. In 95/96, the financial annual per-capita income is US$495. The agricultural products of Pakistan are mainly from Punjab. In Punjab, the handicraft industry has a very long history and the product verities are very rich, including handmade cotton, manual printing and dyeing, embroidery, pottery, carpet, wood carving, bronze ware, enamel ware, silver bracelet, willow rattan products, straw mat and etc. The main mineral resources of Punjab including: salt mines, iron ore, drill earth ore, bleaching clay soil, gypsum, limestone, refractory mortar and clay. The crude output also occupies a very important position in Pakistan. There is also uranium ore in the DG Khan district.

2.3.5 Overview of Power System

2.3.5.1 Pakistan

There are 53 various large and middle-sized power plants in Pakistan (stations), with a total installed capacity of 20,839 MW. Power source structure mainly consists of thermal power generation and hydroelectric power generation secondarily. There are 35 thermal power plants (34 plants are fired by fuel oil and gas and one is fired by coal), with an installed capacity of 12515 MW, accounting for 66.2% of the total installed capacity. There are 8 large hydropower plants, with an installed capacity of 6644 MW, accounting for 32%, and dozens of small hydropower plants, with an installed capacity of 106 MW. Nuclear power plants take up a small portion in the structure. In addition, the use of wind power, solar energy, bio-energy and other renewable energy sources are still in the exploration and trial phase,

Although the total installed capacity of the power plants in Pakistan reached 20,839 MW by the end of 2013, the actual transmission capacity is only 15,140 MW due to line losses during the transmission and other reasons. Therefore, power supply was insufficient, with more than 2,000 MW shortfall 2007.

The current situation of the power grid system in Pakistan is as follows:

The main transmission grid of WAPDA consists of 500kV and 220kV transmission lines. The 500kV transmission line is connected to hydropower plants in the North and the load center of the middle and southern parts of Pakistan. The 500kV transmission line reached 5,078km by the end of 2012. By now, the length of 220kV, 132kV and 66 kV lines is 43,676 km. The power distribution network consists of 33 kV, 11kV and 0.4 kV lines, of which the total length is 257,000 km.

The KESC transmission system consists of 220 kV, 132kV and 66 kV systems, having a length of 867 km. The total length of the distribution network lines is 12,000 km, with voltage 11kV and 0.4kV .

Pakistan's power sector is currently afflicted by a number of challenges that have led to a crisis:

1) A yawning supply-demand gap where the demand for electricity far outstrips the current generation capacity leading to gaps of up to 4,500 – 5,500 MW. The supply-demand gap has continuously grown over the past 5 years until reaching the existing levels. Such an enormous gap has led to load-shedding of 12-16 hours across the country.

2) Highly expensive generation of electricity (~Rs 12/- unit) due to an increased dependence on expensive thermal fuel sources (44% of total generation). RFO, HSD, and Mixed are the biggest sources of thermal electricity generation in Pakistan and range in price from ~Rs 12/- unit for mixed, to ~Rs 17/- unit for RFO, and a tremendously expensive ~Rs 23/- unit for HSD. Dependence on such expensive fuel sources has forced Pakistan to create electricity at rates that cannot be afforded by the general population.

3) A terribly inefficient power transmission and distribution system that currently records 23-25% losses due to poor infrastructure, mismanagement, and theft of electricity is a major problem. The cost of delivering a unit of electricity to the end consumer has been estimated at Rs. 14.70 by NEPRA. This means that the inefficiencies are costing the tax payers additional 2.70 rupees per unit above the cost of generation (~Rs. 12). The Ministry of Water and Power has estimated the true cost of delivering a unit of electricity to the end consumer at greater than Rs. 15.60 after taking into account the collection losses and the real losses to the distribution companies. If the system assumes the NEPRA suggested transmission and

distribution loss of 16%, the theft alone is estimated to be costing the national exchequer over Rs.140 billion annually.

4) The aforementioned inefficiencies, theft, and high cost of generation are resulting in debilitating levels of subsidies and circular debt. Reducing these losses would lead to significant improvement in the bankability and profitability of the sector, and could be used to improve the efficiency of the power system / network as a whole.

2.3.5.2 Agencies involved in Power Genration, Transmission and Distribution

In Pakistan, the following power utilities in the public and private sectors are providing the necessary services to the population.

- Pakistan Water and Power Development Authority (WAPDA), which has been unbundled into Power Distribution Companies (DISCOs), National Transmission and Dispatch Co. Ltd (NTDC) and Generation Companies (GENCOs), and which are currently in the process of being privatized in accordance with the policy of the Government of Pakistan.
- Karachi Electric Supply Corporation (KESC), which already stands privatized.
- Pakistan Atomic Energy Commission (PAEC)
- Independent Power Producers (IPPs)

Out of the total generation capacity of about 20,839 MW in the country, 11,284 MW is owned by WAPDA hydel and GENCOs, 1,756 MW by KESC, 462 MW by PAEC, 285 MW by Rental and about 7,050 MW by IPPs.

WAPDA supplies power to the whole of Pakistan except the metropolitan city of Karachi, for which KESC is the main source of supply. The transmission systems of WAPDA and KESC are interconnected through 220kV double circuit transmission line, to allow WAPDA to counter the deficit of power supply in the Karachi area. A new 500 / 220 KV interconnection with KESC for supply from HUBCO 500KV line has also been completed.

2.3.6 Power Supply Planning

2.3.6.1 Load Forecast

1) Pakistan

In accordance with *HYDRO POTENTIAL IN PAKISTAN* developed by the Pakistan Water and Power Development Authority (hereinafter referred to as WAPDA) in May of 2010, it is estimated that the maximum load of Pakistan would be 36,217 MW in 2015, 54,359MW in 2020 and 113,695MW in 2030.

The long-term power development planning (up to 2030) of Pakistan is as follows:

A. Encourage employing PPP or BOT methods to construct large and middle-sized hydropower plants over main rivers (especially the Indus River) and small hydropower plants over canals and small rivers, striving to improve the installed capacity of the hydropower generation to 32,660 MW before 2030.

B. Utilize the potential of coal power to the largest extent, striving to improve the installed capacity of coal-fired power plants to around 20,000 MW, accounting for 18% of the total generating capacity.

C. Actively develop the nuclear power plants, striving to make the total installed capacity of nuclear power plants upto 8,800 MW in 2030.

D. Vigorously develop renewable energy sources, striving to make the energy produced with renewable energy sources reach 5% of the total generated energy (9,700 MW) before 2030.

E. Improvement in the maintenance of the transmission network to enhance transmission capacity and reduce power losses.

(2) Punjab

According to the latest load forecast, the projected load growth by 2030 is estimated to be 101,478 MW, while the load forecast up to the year 2010 for Punjab Province is about 13,500 MW. This load growth requires a proper expanded generation plan to meet the shortfall. Punjab has sufficient resources to generate about 600 MW from 317 hydel locations. This potential is in addition to other options available for thermal generation based on indigenous fuel such as coal, biomass and gas etc. Coal reserves are estimated at 235 million tons which are located in districts Chakwal, Jhelum, Khushab and Mianwali in Punjab. Coal quality is sub-bituminous type having calorific value of 7,000 to 12,000 BTU and is suitable for power generation.

2.3.6.2 Power Supply Scope of Proposed QA Solar Park

With a planned total installed capacity of 1,000MW, Quaid-e-Azam Solar Park will be developed in three phases. The installed capacity of 100MW is going to be developed in phase-I, 300MW in phase-II and 600MW in phase-III. The Solar park will be connected to the national grid system.

2.3.6.3 Power Grid Planning

NTDC is required to ensure evacuation of power from the said park through 220 kV Transmission Lines while MEPCO is to evacuate power from the 132 kV network. MEPCO network around the Quaid-E-Azam Solar Park comprises of 33 kV, 66 kV and 132 kV voltage levels.

1) Phase - I (100 MW):

Scope of Work includes 132 kV double circuit transmission line for interconnection of solar power plant with 132 kV Bahawalpur to Lal Sohanra single circuit transmission line (4km).

2) Phase - II (400 MW):

Scope of Work includes:

A. 132 kV T/Line, approx. 8 km, for connecting with existing BWP Cantt. - Lal Sohanra T/Line.

B. 132 kV T/Line, approx. 4 km, for connecting with existing BWP – Lal Sohanra T/Line.

C. 132 kV T/Line, approx. 40 km, from Bahawalpur 220 kV G/S to Lodharan.

3) Phase - III (1,000 MW):

Scope of Work:

A. A new 220/132 kV G/S at Quaid-E-Azam Solar Park near Lal-Sohanra.

B. 220 kV T/Line, approx. 40 km, from Quaid-E-Azam Solar Park to Bahawalpur.

C. Three 132 kV T/Lines, each approx. 8 km, for connecting individual solar projects to 220 kV G/S within Quaid-E-Azam Solar Park.

2.3.7 Transportation

The traffic network is well developed around Bahawalpur, where many roads/highways Bahawalpur, Uch Sharif, Yazman and Hasilpur.

The QA Solar Park is located about 15 km southeast of Bahawalpur, and is easily accessible via various jeepable earthen roads; 8.0km south of the Hasilpur Road, 8.33km southwest of Bahawalpur airport, 6.0km east of the Yazman BWP Road and 5.5km east of the Lal Sohanra National Park. The ground elevation of the Park varies from 119m to130m above sea level. General slope of the area is towards north-east, The terrain is flat in the some parts in the north east and mid-west, while the remaining area is undulating having sand dunes all over. Sparse wild vegetation covers the land surface.

Chapter 3

SCHEME OF GENERAL LAYOUT

3.1 GENERAL LAYOUT

3.1.1 Site Selection and Planning Scope of the Park

The proposed site for Quaid-e-Azam Solar Park is located in Cholistan desert, near Lal-Sohanra National park in Bahawalpur District. This site was selected by the Energy Department, Government of the Punjab, in view of availability of abundant land with adequate sunshine, availability of 132kV transmission line within the project area for immediate evacuation of power up to 100M W, proximity of the grid station at Bahawalpur and easy accessibility. The site lies 8.0km south of the Bahawalpur-Hasilpur highway, 6.0km east of the Bahawalpur-Yazman road, and the north of Kudwala road. Various water sources are also available nearby. The total available land area is 10,000 acres which is mostly barren. This scheme has planned that the total planning area is about 5,114.42 acres.

3.1.2 External Facilities

3.1.2.1 Approach Road

Presently the QA Solar Park site is accessible via jeep tracks off-taking from the road along Ahmadpur Canal. For reliable access, C&W Department is already constructing a road off-taking from the Bahawalpur-Hasilpur road and ending at the entrance o fthe solar park almost in the middle of its northern periphery.

3.1.2.2 Power Evacuation Arrangements

Presently a 132 kV transmission line is passing obliquely through the eastern half of the project area. According to NTDC & MEPCO, this power line is capable of evacuating 100 MW at any time. The system would be needed to be upgraded in order to evacuate another 300 MW. To evacuate the remaining 600 MW, a 220 kV line will have to be extended to the project area which will also require a step-up station to be set up in the southern part of the project area.

3.1.2.3 Water Supply

The QA Solar Park would require good quality water for the staff working at the power plants as well as for regular washing of PV solar panels. A number of water supply sources are available around the project area.

Ahmadpur Canal flows to the northern part of the project area. Some existing tube wells along the canal show promise of good quality drinking water, which is also suitable for washing the PV solar panels.

Desert Canal flows to the east of the project area at a distance of about 5.5 km. Patisar distributary off-taking from it is closer to the southern part of the project area and could be considered for supply of water to the solar park, after necessary treatment, to make it useable for panel-washing purposes. In order to make it potable, it has to be either treated further, or some other source of drinking water has to be considered.

The ground water is brakish within the project area and cannot be a reliable source of uninterrupted water supply for the whole solar park area. As such water will have to be brought from an outside source, on which discussion is given later in this report.

3.1.3 Planning Concept of QA Solar Park

The general planning of the solar park can be described as “One center, one station, two axles and multiple areas”, where:

- ✧ One center: General services zone.
- ✧ One station: 220kV collection and step-up station.
- ✧ Two axles: The two main corridors (eastern and western corridors) to accommodate primary roads, power transmission lines, telecommunication lines, water pipelines, and other facilities for easy connections to the solar farms on both sides.
- ✧ Multiple areas: Multiple solar power generation farms in modular fashion, centering on the main corridors. The installed capacity of each of the 20 modules is 50MWp, totaling to 1,000 MWp. Modules can be inter-connected to have plants of larger sizes in multiples of 50 MWp.
- ✧ Generally 5 acres per megawatt is considered to be on appropriate size to determine the total size of a solar farm. As such for preliminary planning the land area for each 50 MWp farm was taken as 250 acres.

3.1.4 Layout Plan and Functions

For optimum land utilization and for minimizing point to point distances within the Solar Park, the solar farms have been planned in rectangular shape as much as possible, with direct and convenient approach to the main corridors. However, since the overall land shape of the park is somewhat irregular and a 132kV power transmission line passes over across the site, some of the plots adjacent to the corridor have trapezoidal shapes.

The general services zone has been placed right next to the entrance of the park on the northern side for convenient access from both outside and within the farm.

In view of the large installed capacity of the solar park, and considering the factors like service radius and power transmission, it is proposed to evacuate the power generated by phase-I and phase-II solar farms through the existing 132KV line. For phase-III, new 132KV lines will be installed in the western corridor for evacuating power from farms and delivering it to the 220kV step-up station which is to be established at the southern end of the western corridor.

In order to reduce investment and simplify power evacuation, a 132kV step-up station will be provided within every 50MW farm by the developer for connection to the 132kV lines.

3.1.5 General Layout of Photovoltaic Solar farm

Eight (8) solar farm plots are proposed to be provided on both sides of the eastern corridor while the western corridor will have 12 plots on both sides. Inside a solar farm generally, there may be an office building and a control room near the entrance to the farm. The power generation area would contain cell arrays, inverter rooms, box-type transformer and maintenance channel. An inverter room shall be provided for each sub-array, to be located in the center of the sub-array. Keeping in view the available area and topography, the cell arrays may use sub-arrays or combination of sub-arrays, to achieve the best layout plan, which makes full use of the land, saves connecting cables and shortens the routine patrol line. The road system inside the site should be convenient for the transportation of large equipment and for meeting the requirements of routine inspection and maintenance. Refer drawing No. 3 for general layout plan of the Quaid-e-Azam Solar Park.

3.1.6 Land Treatment

To avoid the environmental impact, soil loosening effects by excessive excavation, and for reducing the cost of site formation works, land leveling within the solar farms is not recommended. As various farms are to be developed by different sponsors, they can, if need be, carry out site formation according to their own design and planning. To reduce dust, they may cover the land with gravels or any other such material.

3.2 PLANNING SCHEME

3.2.1 Type of Equipment for Solar Farms

Keeping in view the trends of international solar cell market, the technical features of various types of solar cells, and the solar energy resources and climatic features of the project area, it is recommended to use fixed-installation type x-Si solar cell components (C-Si or P-Si). The general layout of the park has therefore been planned according to the land use indicators of fixed-installation type x-Si solar cell components. If the investors plan to use some other type of equipment, the installed capacity shall be adjusted according to the planned land area.

3.2.2 Corridor Width

For optimum land utilization, convenient management and prevention of shadows of transmission lines over the solar panels, the width of the corridor along the 132kV western (Corridor A on Drawing 4) is proposed to be 170 meters. Sub-corridor C will be 170 meters wide as well. Corridors A & C will jointly evacuate 400MW from phase-I & phase-II solar farms. Corridor B is proposed to have a width of 200 meters to accommodate 132KV power lines for evacuating a total of 600 MW.

3.2.2 Land Utilization

To summarize the above land of the solar park will be occupied by main and sub-corridors, a general services zone, a step-up station and photovoltaic solar power plants. The total area covered by these components is 5,114.42 acres. The area under each of these components is shown in Table 3.1.

Table 3.1 Summary of Land Utilization of Quaid-E-Azam Solar Park

Serial Number	Component	Land Area (acres)	Statistics of Area in Every Construction Phase		
			Phase I	Phase II	Phase III
1	Land for photovoltaic power plant	4370.27	505.03	1292.35	2572.89
2	220kV step-up station	5.04	0	0	5.04
3	Comprehensive service zone	126.78	126.78	0	0
4	Pump station, water supply station, sewage plant	101.3	101.3	0	0
5	Roads	511.03	62.38	166.01	282.42
	Total	5114.42	795.49	1458.36	2860.57

3.3 PLANNING OF ROAD WORKS

3.3.1 External Traffic

To connect the solar park to the existing road network in the area, an approach road is under construction by C&W Department which will end at the entrance/exit gate of the park, to be located in almost middle of its northern boundary.

3.3.2 Internal Roads of the Park

1) Road Traffic Planning

The main roads of the solar park are planned through the western and eastern corridors and inter-connected at the northern and southern boundaries in the form of a ring for ensuring complete connection to all the solar farms and the general services area. The main road in the eastern corridor will be located parallel to the existing 132 KV transmission line at a minimum distance of 30 m for safety reasons. Road-C will be provided in the sub-corridor C while road B will pass through corridor B. Besides accommodating the roads, the corridors will also be used for overhead power lines, buried water pipelines, telecommunication lines and other utilities.

The main roads passing through the corridors have a total width of 12.7 meters with a carriageway of 7.3 meters, and has a 50 mm thick asphalt wearing course over water bound macadam base, treated shoulders 1.2 m wide and earthen berms 1.5 m wide. Cross slope of the road will be 1.5% for easy surface drainage. As the terrain is sandy, side slopes are adopted as 1:4 for stability purpose. Right of way for the roads is recommended as 40m.

2) Design of Road Works

The roads will turn orthogonally at 90° as much as possible, Precautionary lights are recommended along the roads. Considering the small population, and light traffic, the road turnings are planned to be rounded off only at the roadway edge.

No public transportation will be permitted to enter the solar park. Solar farm sponsors will arrange vehicles according to their own needs for travelling in and out of the farm along with parking lots within their farm boundaries.

3) Road Vertical Design

As the land within the solar park is undulating, the range of longitudinal gradient of roads is recommended to be 0.3%. In specific cases like escarpments, the gradient limitation may be relaxed according to site conditions. In order to ensure smooth longitudinal curve of the road, cut and fill balance method should be used . Factors such as comfort, smooth ride, engineering parameters and proper visibility are to be considered in vertical design, especially at road turnings whereas the longitudinal slopes of roads on both sides of the turning should remain the same.

4) Road bed / Subgrade

The road bed is required to be strong, stable, economical and should be prepared according to the local conditions including geology, hydrology and available material as well as other construction requirements. Accordingly the subgrade is proposed to have a minimum thickness of 300mm having CBR values 8%. Compaction of fill material in the subgrade should be 95% of AASHTO T-180

(MDD). Borrow pits and spoil heaps should be properly dressed to avoid any hazards.

5) Pavement

It is expected that during construction of the solar farms, there will be considerable vehicle movement on the roads, however during the operation stage, the traffic will be quite light. The road pavement has been accordingly designed on the basis of one million ESAL traffic load and subgrade CBR requirement of 8%

The road surface needs to be stable and strong enough to meet the requirements of being smooth, anti-sliding and having a good drain system. Accordingly, the consultants have proposed a sub-base thickness of 150 mm, overlain with 175 mm thick water bound macadam meeting the standard AASHTO specification. The asphalt wearing course is designed to have a thickness of 50 mm as shown on figure 9.

The shoulders will have a double surface treatment over the 150 mm thick water bound macadam. Thickness of sub-base and subgrade will be the same as that for the main carriageway

The roads are proposed to be constructed phase-wise based on traffic needs. The first road is proposed to be built from the end of access road being constructed by C&W up to the phase-I area.

6) Road Traffic Safety Facilities

Necessary traffic safety facilities are proposed according to safety regulations, to ensure the safety of vehicles and pedestrians as follows:

A. For sharp turns with small range of visibility, warning signs and mirrors are proposed. Proper lane marking should be done on the roads.

B. Necessary traffic signs such as directional signs will be provided. The names, locations, shapes, sizes and colors of signs shall be designed based on current regulations.

3.4 WATER SUPPLY WORKS

3.4.1 Quality of Water for Washing PV Solar Panels

Photovoltaic panels are constantly exposed to various types of weather and are thus a target for dirt, dust, industrial residues, atmospheric pollution, algae, moss, bird droppings, etc. The ground stratum of the proposed project area, being located in northern part of the Cholistan desert, is composed of fine silty sand, which makes the atmosphere dusty throughout the summer months. PV solar panels are prone to be covered with fine dust. During dust storms which are not infrequent in the desert area, the sand deposited on them, if not cleaned properly, may also cause abrasion. This necessitates frequent washing to maintain them at optimum efficiency in generating solar power

The agents responsible for deterioration of the surfaces also include the chemicals used during cleaning. They attract dust and dirt and further accelerate the deterioration process. Moreover, they have a negative effect on the appearance and, above all, the function of the panels. The presence of these elements on the panel’s surface prevents the sun’s rays from filtering onto the panel’s photovoltaic cells completely, reducing the solar performance and therefore efficiency. Therefore cleaning should be done with plain water without any detergents.

Accumulated dirt residues reduce efficiency and may damage the material the panels are made from. Cleaning is therefore an indispensable part of the maintenance process the frequency of the cleaning depends on the geographic area and climate.

Solar panels in the desert conditions need to be cleaned almost daily with water otherwise their performance is reduced. It is recommended that the panels installed in these conditions pass the “sandstorm” Test. The test is run according to the IEC 60068 protocol by SGS, a body responsible for inspection, verification, testing and certification. Those tests have already proven the high yield of the panels that use monocrystalline (c-Si) in solar arid conditions, ensuring reliability and durability in extreme conditions.

High tech researchers around the world are working on and testing dust-resistant solutions that would keep the panels clean. Some of these include:

1. Nomadd (no-water mechanical automated dusting device) pushes dust and dirt away from panel surfaces with an automated “dry sweep”.
2. Special coatings are being developed and tested. Ultra thin surface treatment developed by Chamelic that can just be applied to the routine wash that can repel dust for up to 8 weeks.
3. Machinery that uses only steam to clean panels with partial recycle of their water consumption, hence drastically reducing the water requirement is being tested in Saudi Arabia.

However, such devices are yet to be time-tested and commercialized. At this juncture, therefore, it is advisable to use the customary practice of using good quality water for washing the panels followed by careful wiping.

Cleaning solar panels with water containing harsh residues like sand will scratch the solar panels or cause smearing and therefore reduce efficiency. Turbid water also leaves a film on the panels and is not recommended for washing them. Thus ruling out the use of detergents and sediment carrying or turbid water

Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal soil) suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a filter with two-micrometer (nominal size, or smaller) pores.

Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L), also referred to as parts per million (ppm). TDS is directly related to the purity of water and the quality of water purification systems and affects everything that consumes, lives in, or uses water, whether organic or inorganic.

Total dissolved solids are differentiated from total suspended solids (TSS), like clayey material and dust, in that the latter cannot pass through a sieve of two micrometers and yet are indefinitely suspended in solution. The term "settle able solids" refers to material of any size that will not remain suspended or dissolved in a holding tank not subject to motion, and excludes both TDS and TSS. Settle able solids may include larger particulate matter or insoluble molecules. Even if settle able solids are removed by sedimentation the TSS are likely to smear the solar panels.

In order to clean solar panels without leaving any residue, the PPM levels need to be less than 50. This will only be possible with reversed osmosis or deionization which would be highly expensive. Cleaning solar panels with normal water and still leave acceptable residue levels should have PPM levels as low as possible and in no case should they exceed 500. In general it is considered that any water that is fit for drinking, is fit for washing of PV solar panels.

3.4.2 Propriety of Water from Various Water Sources

As stated earlier, the possible sources of water are as follows:

(i) Tube Wells in the project area
(ii) Tube wells along Ahmedpur East Branch Canal
(iii) Surface water from Desert Branch Canal

The Consultants have carried out studies of all the three sources as discussed in the following:

3.4.2.1 Tube-wells within the Project Area

Documented data is available with Punjab Irrigation Department (PID) regarding depth to water table along irrigation channels in Punjab. The channel nearest to the project area is 3L/BC running at a distance of about 7.5 km parallel to the project’s northern boundary. The data 0f 2009-2011 shows the depth to water table between 43 and 48 feet below ground level according to the depth to water table data of Punjab Irrigation Department the 3L/BC minor.

Some tube wells have also been found operating in the northern part of the project area at about the same depth. However this water is brackish in quality as confirmed by the probes made for geotechnical investigations, where water table was encountered. The water quality map prepared by Irrigation department for Bahawalpur zone (reproduced below as Fig. 3.1A) also shows that the project area lies in the area where water is unfit for drinking.

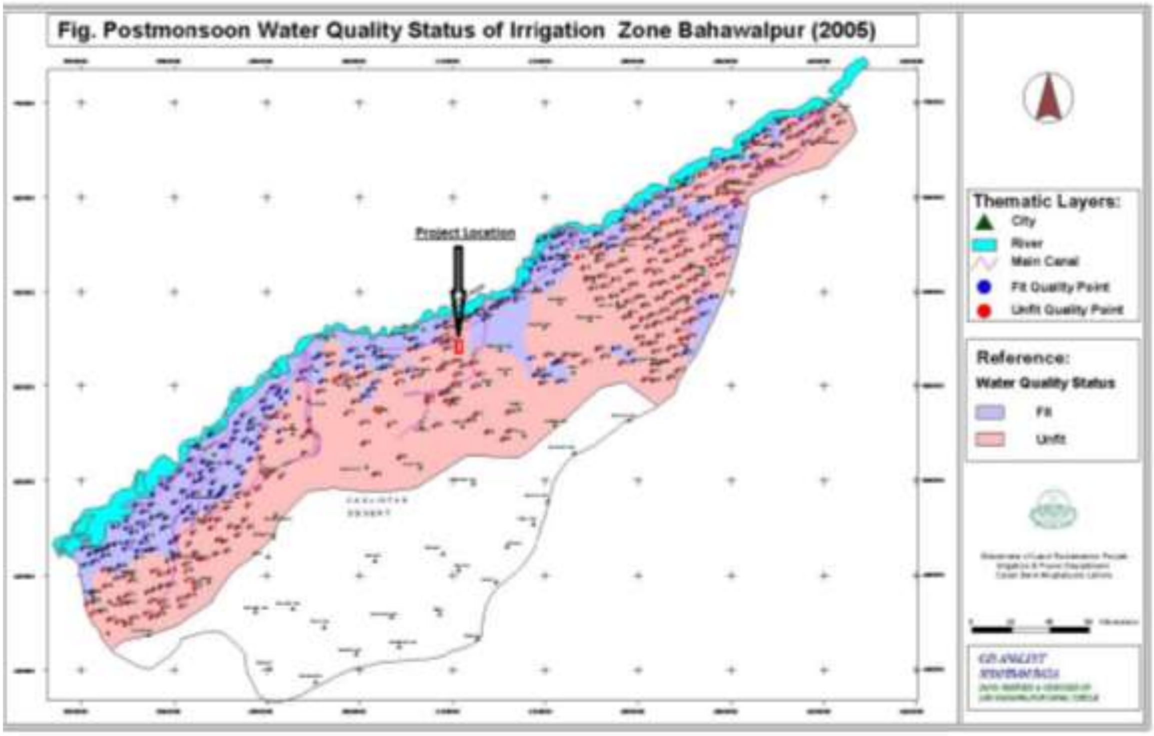


Fig. 3.1 A Water Quality Map

In view of poor water quality, use of water from aquifer underlying the project area is not recommended.

3.4.2.2 Tube wells along Ahmadpur East Branch Canal

Existing tube wells along this canal exhibit good quality water. Naturally, this water is neither turbid, nor does it contain any suspended or settle able solids after having passed through natural filtration process as well as through the filter around the tube well screen. As such it is highly suitable for the purpose if it is not brackish. Laboratory tests carried out on water obtained from these tube wells show TDS as low as 300 ppm against a limit of 1000 ppm for drinking water according to WHO. On the basis of quality, the water from tube wells along Ahmadpur East canal can therefore be recommended for washing of PV panels.

The consultants have also carried out 15 probes for electrical resistivity tests parallel to the canal to establish the availability of adequate water throughout the year. Location of the probes in shown in the attached map.

For estimation of long term availability of groundwater on long term basis aquifer parameters i.e. Transmissivity, storage coefficient etc. are pre-requisite. These parameters are to be determined by performing aquifer test (pumping test), which is at this stage is not possible; however, it will be conducted when groundwater source is finally decided for development. At this stage, estimation has been made on the basis of average hydraulic conductivity (60 ft./day) of aquifer material composed of fine to medium sand, thickness of aquifer i.e., 40m (131 ft.) and a tube well of capacity 1 cfs.

For sustainable groundwater development, the aquifer must be recharged to compensate the decline in water table in response to pumping. The possible recharge sources of the project area are:

1. River Sutlej;
2. Ahmadpur and Desert Branch Canals;
3. Canal irrigated fields; and
4. Rainfall.

The Sutlej River is located about 14km and Ahmadpur Branch Canal is about 6km from the project area. The canal is non-perennial and flows for 6 months during a year. Therefore, long term availability of groundwater has been estimated on the basis of continuous pumping of groundwater from a well of capacity 1.0 cfs for 6 months. For the estimation, modified non-equilibrium formula has been used as given below:

$$S = \frac{264\,Q}{T} \; log_{10} \frac{0.3\,Tt}{r^2\,S}$$

Where

Q= well yield or pumping in gpm

T= coefficient of transmissivity in gpt/ft

“t”= time since pumping started in days

“r”= distance in feet where drawdown is to be estimated

S= storage coefficient or specific yield, dimensionless.

For calculating drawdown in the well, following parameters have been assumed:

- Coefficient of transmissivity 58,797 gpd/ft;
- Specific yield 20%
- Tubewell is pumping continuously for six months i.e. t= 180 days
- Constant discharge of the tube well is 450gpm (1cfs)

Calculations reveal that:

- Drawdown in the well due to aquifer loss would be 10.5 ft; and
- Radius of influence may extend up to about 400ft only.

The aquifer is much more extensive as compared to the radius of influence of a well pumping at a constant rate of 1cfs for 6months. Accordingly, 2.5

cfs can safely be pumped, by installing 1.0 cfs capacity wells, from the aquifer even if it is not recharged for six months.

Water from this source will have to be delivered to the site through forced mains, which may discharge into storage tanks. For the proposed discharge of about 2.1 cusecs, the total cost of the tube wells and forced mains comes to about Rs. 75 million

3.4.2.3 Surface water from Patisar distributary:

Possibility of using surface water from this distributary has also been studied. This distributary has a discharge of 30 cusecs & off takes at RD 49200/R of Desert Branch. It is an entirely Forest Channel with no approved long-section or regular outlets. For accommodating additional water, the distributary would require enhancement of the capacity in a length of 6.45 km and taking out a 8.78 km long new minor from it, which can deliver water to the southern part of the proposed solar park. Punjab irrigation Department also proposes to line Patisar distributary and the proposed minor will also be a lined channel. It is important to note that this source would be delivering water to the southern part of the solar park whereas development of the solar part is to logically start from the northern side as its main access is through the northern boundary. In fact, their solar plant for Phase-I (100 MW) is to be tendered shortly, construction of a long conveyance system to Phase-I area, in addition to building more than 15 km long channel and six ponds will require much longer to build.

Besides, the open channels and ponds are exposed to open atmosphere in a desert area where gales and dust storms, especially in summer, would add considerable dust and sand into the water.

As this water would be carrying sediments, it will require treatment, the extent of which will depend on the quality of water. In summers and during flood period, the branch Desert carries substantial sediment load, estimated to range from 1500 – 2000 ppm including settleable solids (heavy sediments) suspended solids (TSS) dissolved solids as well. Out of this the settleable solids will require sedimentation/ settling tanks to remove heavy sediment. Even after sedimentation, TSS and TDS will remain in water. If the solar panels are washed with water containing TSS, the panels will get smeared; reducing their power generation efficiency. For removing TSS, a filtration plant would be required which is estimated to cost about Rs.10 million. In order to remove the suspended sediments, however, a filtration plant would be required. The cost of the system (with earthen storage ponds without filtration plant) will be Rs. 132 million. Adding the cost of filtration plant, the cost will rise to Rs.132 million considering the water quality and economy established by the comparison given above, it is recommended to adopt the option of obtaining 2.5 cusecs of water for Quaid-e-Azam Solar Park by installing tube-wells along Ahmadpur East Branch Canal.

However, in view of the discussion in the meeting held on 27 November, 2013, chaired by Chairman P&D, further studies are required for deciding the water source.

3.5 WATER DEMAND, SOURCE, TRANSMISSION & DISTRIBUTION SYSTEM

3.5.1 Water Demand Criteria:

Water will mainly be required for washing the power generation equipment; mainly solar panels besides some water will also be required for landscaping and for human consumption of solar farm's resident staff. Water consumption criteria for various parameters of the park are depicted in the table 3.2.

Table 3.2 Water Consumption Criteria for Solar Park

No.	Description	Water consumption (10,000 $m^3/km^2.d$)
1	Water for Solar Panel Washing (Photovoltaic power generation)	0.005
2	Landscaping, spraying of roads, water for plant staff etc.	0.0033

3.5.2: Water Quantity:

Based upon the above mentioned criteria, water demand of the park has been calculated as shown in table 3.3. From the table it can be seen that for twenty (20) solar farms in the solar park, daily water consumption would be 1,660 m^3 for the whole park. With tube wells pumping eight hours a day, total demand in terms of discharge comes to 2.04 cusecs.

Table 3.3 Water Consumption in the Solar Park

No.	Description	Daily Water consumption per km^2 (250 Acres)	Area	Daily Water consumption	Daily water consumption with 8 hours Tube well Working
		10,000 $m^3/km^2/day$	(km^2)	(m^3/d)	(ft^3/sec)
1	Water for Solar Panel Washing (Photovoltaic power generation)	0.005	20	1000	1.23
2	Landscaping, spraying of roads, domestic supply etc.	0.0033	20	660	0.81
			Total	1660	2.04

3.5.3 Water Supply Source:

It is proposed to install shallow tube wells along Ahmadpur East Canal which is located in north of the proposed solar park site at a distance of about 8 kms. There is continuous recharging of the groundwater aquifer from the seepage of the canal and quality of the water is within the limits as prescribed in WHO standards for drinking water. Water extracted from tube wells is equally good for solar panels washing. It is proposed to install seven (7) tub wells along Ahmadpur Canal. Capacity of the each tube well would be 0.3 cusecs and center to center distance between tube wells would be 500ft. The schematic layout of the water supply scheme is shown in figure 3.1B.

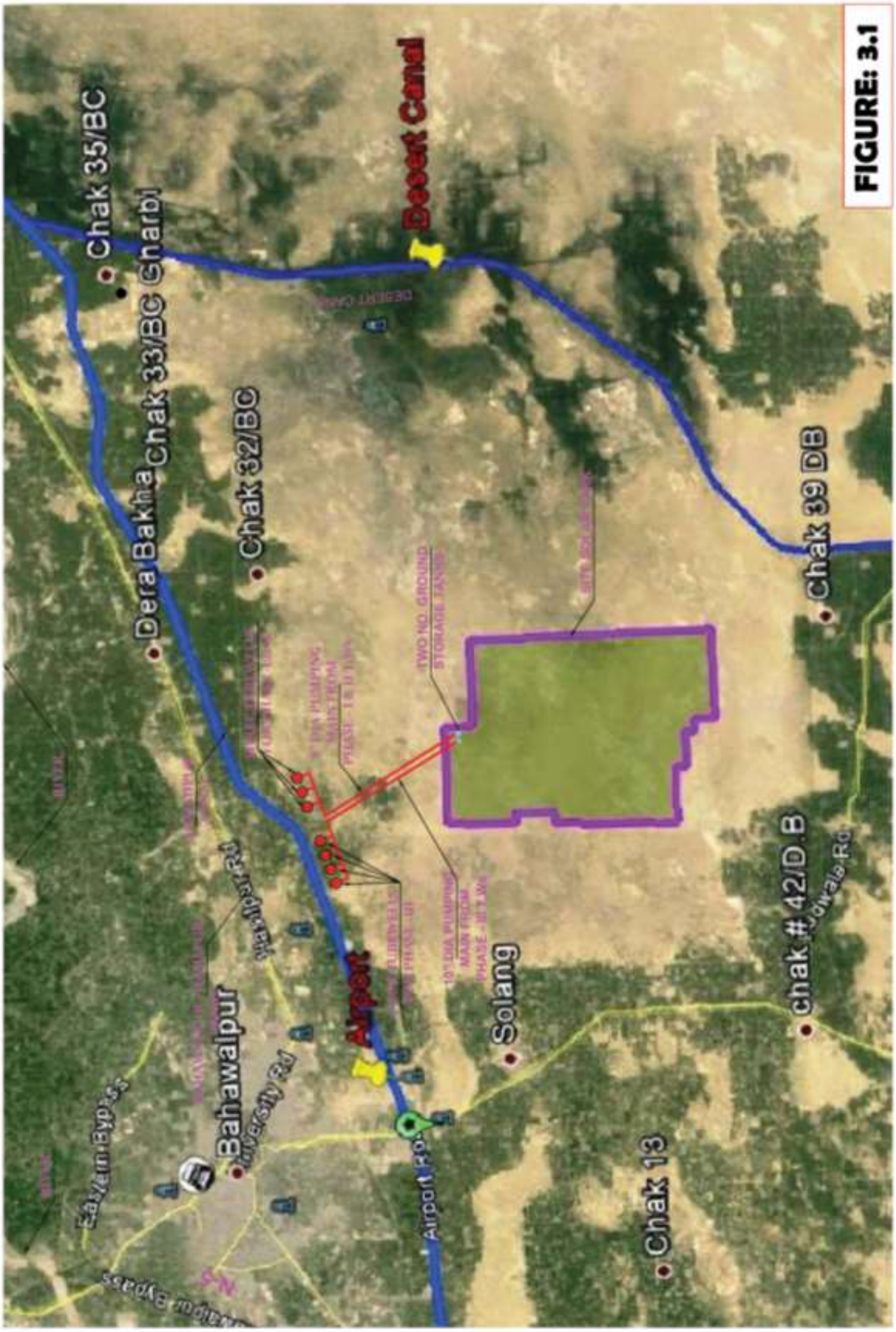


Fig. 3.1 B Schematic Layout of Water Supply Scheme

Phase wise installation of tube wells is recommended. For Phase-I, only two tube wells may be installed out of which one will be standby. For Phase-II and Phase-III tube wells should be installed according to the development scenario.

As per initial investigations of the site and data collected from the already installed tub wells for rural water supply schemes vertical turbine pumps are proposed to be installed at a depth of 90ft to 100ft.

3.5.4 Water Transmission & DISTRIBUTION SYSTEM:

As the water supply source (tube wells site) is almost 8 km away from the solar park site, it is proposed to lay two (2) forced mains from tube wells to the solar park site. One forced main of 8” diameter will take the water extracted from the three (3) tube wells for Phase-I and Phase-II area while the other forced main of 10” diameter will be connected to remaining four (4) tube wells.

At the terminal point of the forced mains as they enter the project area, two R.C.C. covered ground storage tanks of 50,000 gallons each are proposed. The total cost of the tube-wells, transmission system and RCC storage tanks is estimated as Rs. 75 millions.

To supply water to the farms, a combined pumping station for all the three phases is proposed, in which initially pumps will be installed only for Phase-I . Water will be pumped in to two main supply lines which are to be laid in the main corridors of the project area. Water will be delivered to each farm through a 4” diameter outlet. The schematic layout of the water supply system is shown in Drawing No.5.

Each of the farms will have its own ground storage tank arrangement for water storage.

3.5.5 Water supply for construction

It is estimated that for the power plant with a capacity of 100MWp, the maximum daily water consumption would be approximately 300m^3/d. For this purpose the tube wells proposed for phase-I will have to be installed early. Alternatively, surface water from an existing forest water course passing close to the northern boundary of the Phase-I area can be used. By the time work on next solar farms starts, the water supply system would be completed up to those farms.

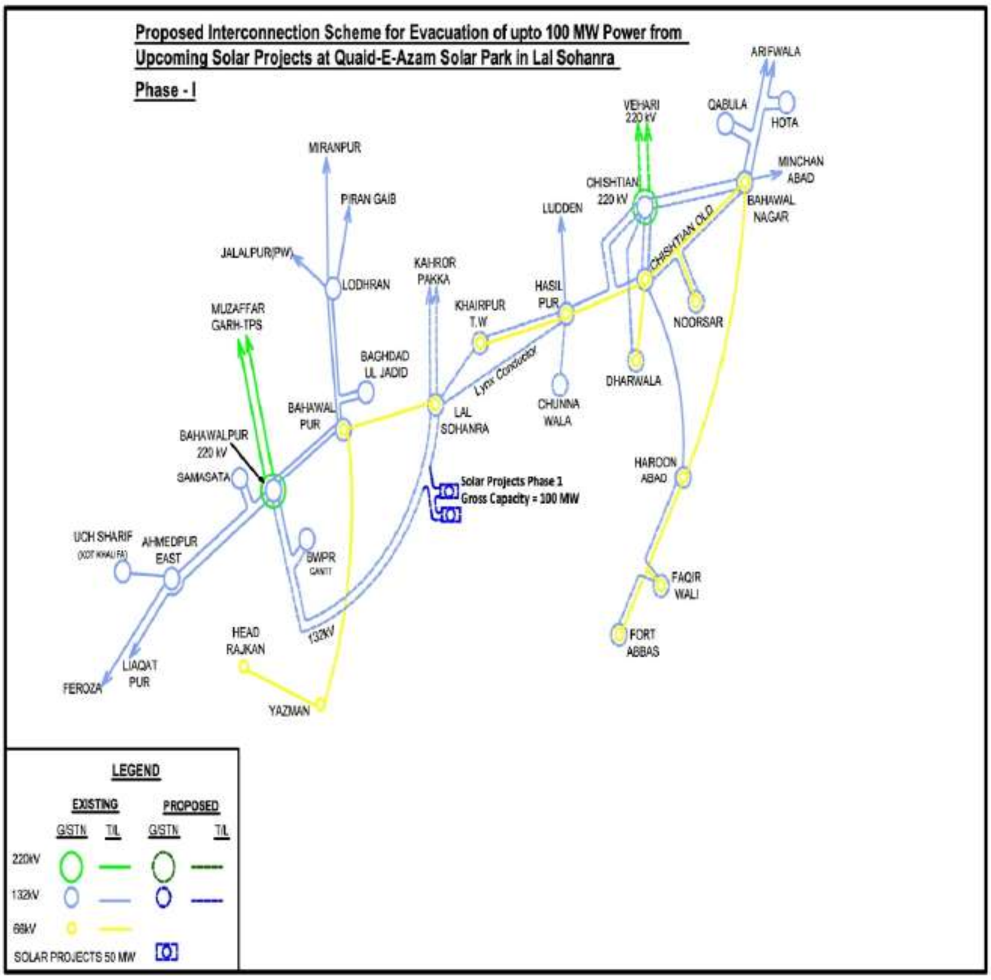
3.6 ELECTRICAL ENGINEERING

3.6.1 Main electrical connection line

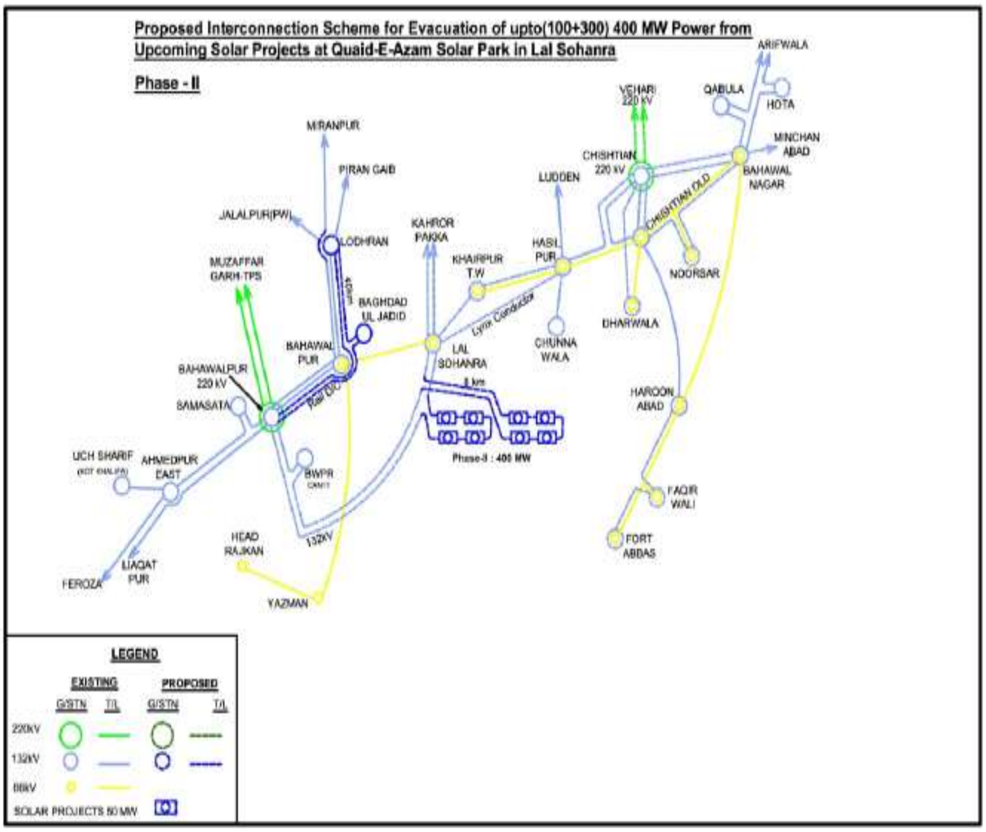
According to the proposal of Quaid-e-Azam Solar Park, the total installed capacity of the Park is 1,000 MWp which shall be developed in three Phases of 100 MWp, 300 MWp and 600 MWp respectively. For planning purposes 20 modular solar farms of 50MWp each are proposed, aggregating to 1,000 MWp. Two or more modules can be combined to make one large farm.

In Phase-I, two modules are to be combined to develop one 100 MWp solar plant. This plant will be connected to the power grid in ring-grid tie with the existing 132kV overhead lines from Lal Sohanra to Samasatta. In Phase-II installed capacity will be 300MWp. In this phase, two 50MWp plants shall be connected to the 132kV ring grid link of Phase-I. The other four 50 MWp plants will be connected to the power grid in ring-grid tie with the same existing 132kV overhead line. In Phase-III there will be 12 farms of 50 MWp each, totaling to 600MWp. Every four

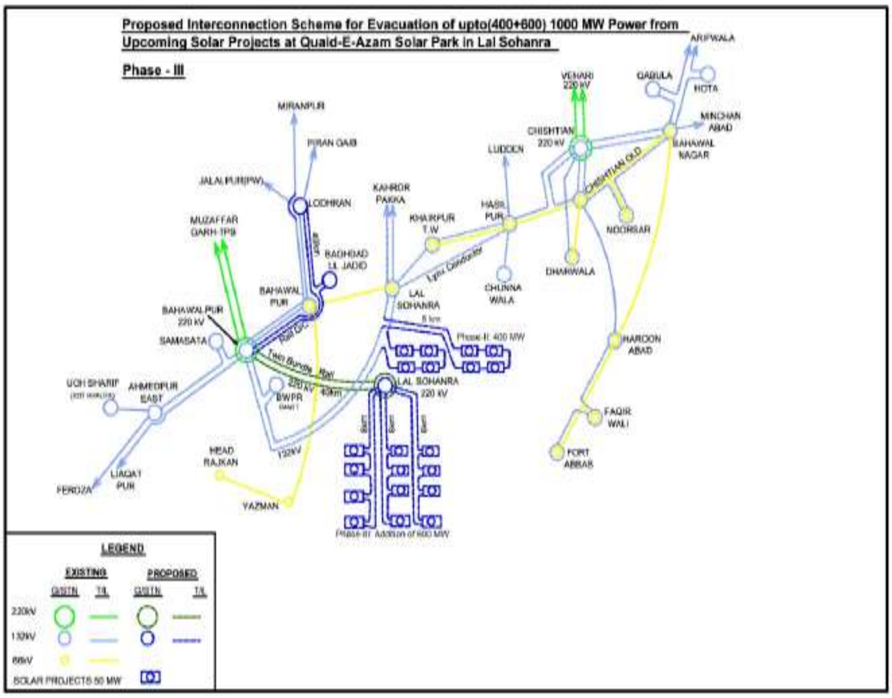
50MWp solar plants in this phase shall be connected to the 132kV side of the new 220kV grid station to be built in the park. The step-up station will be connected to Bahawalpur 220kV grid station with 220kV double circuit, twin bundle conductor line. The 220kV grid station will thus meet the capacity requirement of 600 MWp in Phase-III. Fig. 3.2 (a), (b) & (c) show the output scheme for various development phases. Final output scheme is shown in drawing No. 6.



(a) Phase I (100MWp)



(b) Phase I and II (400MWp)



(c) Phase I, II and III (1,000MWp)

Fig 3.2 Output Scheme for Various Development Phases.

3.6.1.1 Electrical Connection for 33kV Switching Station

Each 50 MWp power plant will have fifty, one (1) MWp sub-arrays and each matrix is composed of two 500kWp photovoltaic power generation units. The 500kWp photovoltaic power generation unit will consist of 500 kWp panel going through a DC cabinet and a 500 kW inverter. Each unit will change DC output of the panels into low voltage AC through a 500kW inverter. Two photovoltaic power generation units in the inverter room will combine the low voltage AC output from the inverters to 33kV through a 1,000kVA double split winding step-up transformer. In order to save cable length, collecting circuit will be laid to connect several box transformers in parallel and then transport the output to regional switching station.

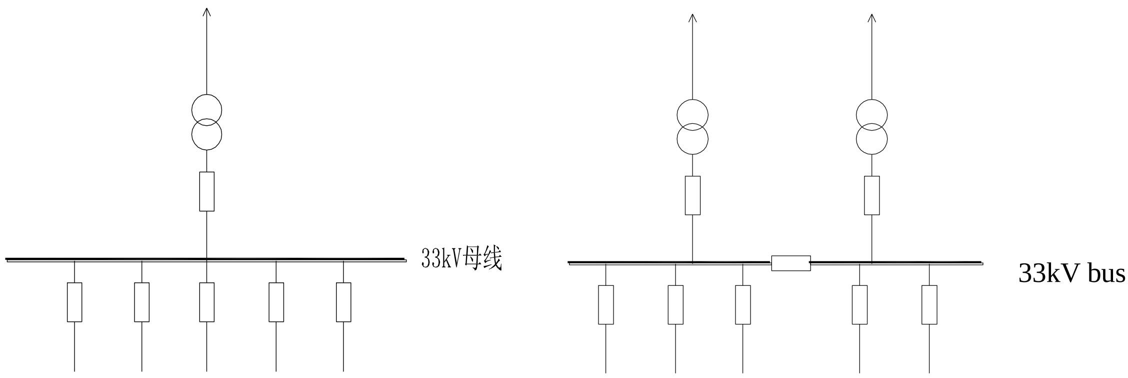
The following two schemes have been considered mainly for 33kV collecting circuit:

Scheme-I: 50MWp to be transported to the switching station by 10 collecting circuits with each circuit of 5MW capacity.

Scheme-II: 50MWp to be transported to the switching station by 5 collecting circuits with each circuit having 10 MW capacity.

Scheme-I needs 5 more switching stations than Scheme II. Investment is high in the preliminary period, but reliability is high as well because fault in any circuit will influence only 10% output of the station. In Scheme-II investment is less as compared to Scheme I, but 20% output of the station will be affected once the circuit fault occurs. However Scheme-II is recommended as it is more economical.

Single Bus and Single Bus Section are mainly used for 33kV switching station connection as shown in Fig. 3.2. For single bus, connection is simple requires less equipment and is easier to operate. However, it is not flexible or reliable enough. The whole station shall be out of operation during a fault or maintenance/inspection of the bus. It is suitable for a station with small installed capacity and with fewer circuits. Single Bus Section is more complicated but more reliable. If a section of bus is out, the section breaker shall automatically isolate that section, while the other sections can function normally and the photovoltaic capacity of the relevant bus can be evacuated normally. Each plant of 50MWp in the park will have a lot of circuits. It is therefore recommended to adopt the Single Bus Section scheme for 33 kV switching station connection.



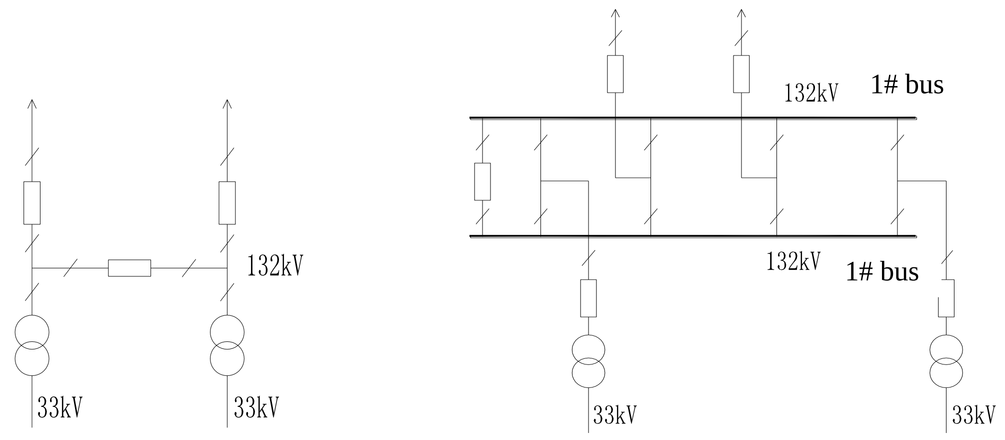
(a) Single bus connection (b) Single bus section connection

Fig. 3.2 Connection Method for 33kV Switching Station

3.6.1.2 Primary Electrical Connection of 132kV Step-up Station

According to the system plan of the photovoltaic park, each power plant of the park shall have an output of 132kV and shall be inter-connected to each other in a ring.

The 132kV step-up station shall mainly adopt inner bridge connection (Single Bus) and double-bus connection, as shown in Fig. 3.3.



(a) Inner bridge connection (b) Double-bus connection

Fig. 3.3 Connection Modes of 132kV Step-up Station

The advantage of inner bridge (single bus) connection is that lesser electrical equipment is required resulting in less floor area and investment cost. All feeders are connected through circuit breakers and sets of isolators. Therefore during fault in any section of the connecting element, the problem can be solved by simply removing the faulty section and the elements connected to it by just opening the breaker contacts and then opening the isolators. As such it has insignificant impact on system operation. Such connection mode is suitable for power plants with less capacity which are not intended for expansion. However the disadvantages are that during a fault, all feeders connected to the bus bar will be disconnected and even during maintenance, all feeders have also to be shut down. It is thus less flexible in operation

The advantages of double-bus connection are: high reliability, i.e., the busbars can be inspected and repaired in turn through switching between two sets of busbar's isolating switch without interrupting the output of photovoltaic power plant. When there is a fault in one set of busbar, the power supply can be recovered quickly. During maintenance of busbar the isolating switch of any circuit only requires disconnection of the circuit to be inspected while other circuits remain uninterrupted; Operation dispatching methods are flexible and expansion is easy. The disadvantages are: The connection is complicated and mis-operation is likely to happen during switching since each circuit is provided with one set of isolator. The structure of the distribution equipment is complicated, and it requires more floor area and investment cost.

Both connection modes are able to meet the requirements of output power and its access to the grid. As the proposed power plants are not intended for future expansion and their operation modes are fixed the double-bus connection will be more expensive and complicated. Therefore the inner bridge connection is recommended for 132kV side of the power plants.

3.6.1.3 Typical Main Electrical Connection of Power Plants

To summarize the above discussion, each plant consists of fifty sub-arrays of one (1) MWp each and is delivered to the switching station by five-circuit current-collecting lines with 10MW delivering capacity each. The 33kV switching station will have a sectionalized single-bus configuration and the 132kV step-up station will have an inner bridge connection. Connection mode of plants is shown in Fig. 3.4.

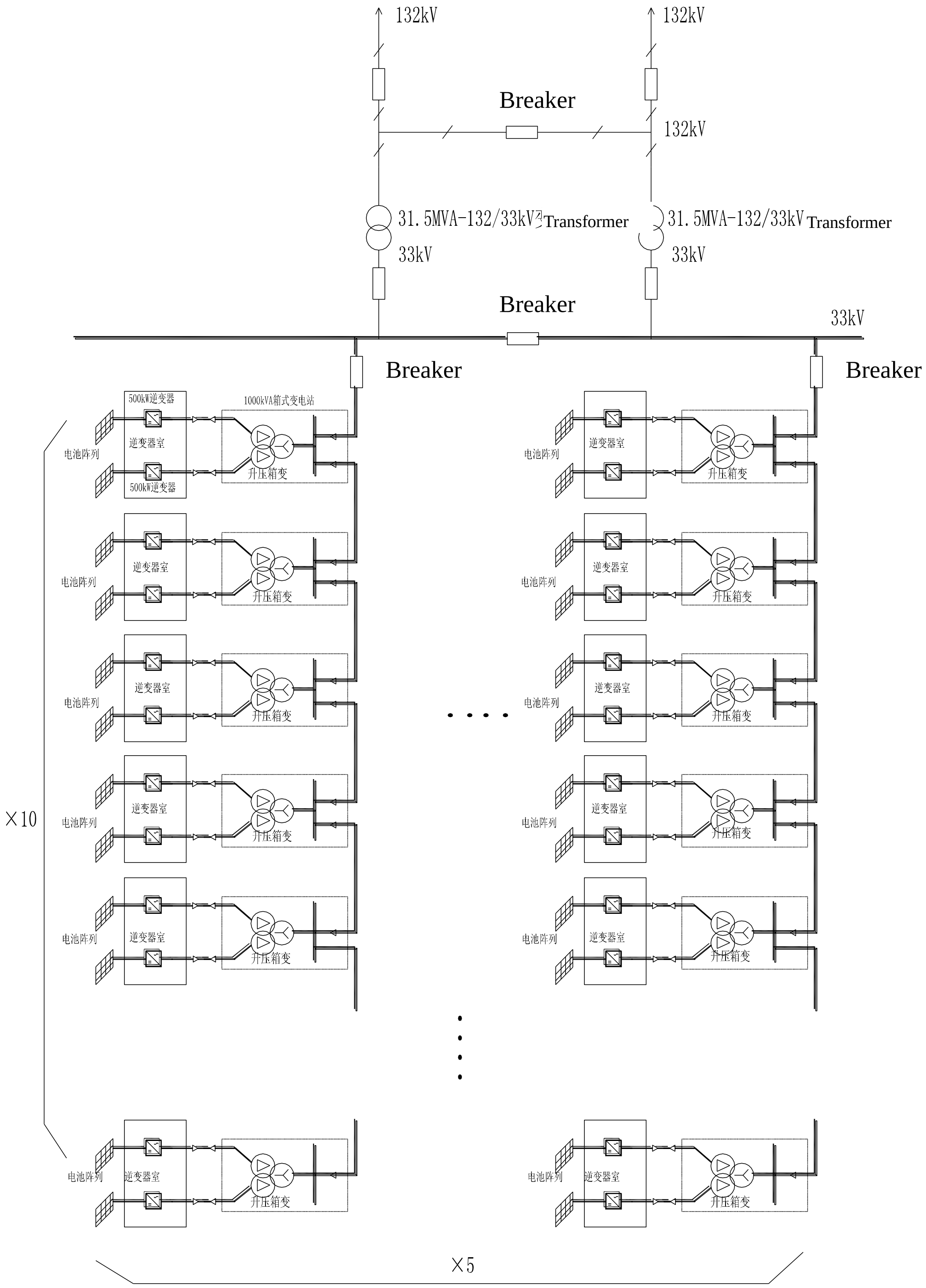


Fig. 3.4 Typical Connection of Power Plant

3.6.2 Auxiliary Power of Photovoltaic Park

3.6.2.1 Load Prediction of Auxiliary Power

Loads of auxiliary power supply of the park mainly consists of two parts.

The first part includes 33/132kV step-up station, 33kV switching station, power for operational of electrical equipment and for buildings in the 220kV grid station as well as power for buildings of the comprehensive service area. The second part includes the inverter room, mainly used for cooling the inverter.

The inverter rooms are large in number and are spread over a large area however the load of each room is rather small (about 6kW). Therefore, LV inlet wire remote power-feeding is not suitable for them. It is recommended that the inverter room should have its own power supply to cater for its own load, i.e., the 6kVA auxiliary transformer carried by each 33kV box-type step-up transformer should be used to feed the inverter room.

Based on the planning characteristics of the park, the step-up station, switching station and comprehensive service area should incorporate load density method for power load prediction. Power load prediction shall fully consider the characteristics of power usage of solar power generation units, with reference to current power use and land use of domestic power generation project to make an exact prediction of the power load at the base. According to the plan, the load index of unit construction land is 5,000kW/ km^2, floor area of step-up station, switching station and service area is about 0.763 km^2, and predicted value of power load of the park is about: 4,000kW.

3.6.2.2 Power Supply Facility

Power supply facilities plan is designed for meeting power transmission capacity requirements, operation reliability, short transmission distance, less power loss, etc., in combination with surrounding electrical power environment, and under the principle of maximum operation reliability, low cost and high flexibility of the entire electrical system.

At present there is an existing 132kV grid station network in this region. Power capacity is sufficient, stable and reliable, which can meet the demand for power supply.

Auxiliary power of each step-up station includes main power supply and standby power supply. Generally, the main power supply is fed by the 33kV side of the busbar of the photovoltaic power generation plants and the standby power supply is fed thourgh an external power source. Auxiliary power shall be subject to the following: Provision of an 11kV power source from outside and use it as standby power supply after stepping it down through a 11/0.4kV transformer; Provision of a circuit from 33kV busbar of the plant and use it as main power supply after stepping it down through a 33/0.4kV transformer and delivering to the station's 0.4kV auxiliary power busbar. Automatic throw-in equipment of standby power supply should be provided between the two power supplies and feeders shall be fed from the 0.4kV busbar to supply to various loads.

The connection method shown below (see Fig. 3.5) is recommended to supply auxiliary power by dividing the step-up stations and service area of the park into two groups. One group includes the service zone and the power plants Phase-I and Phase-II areas, while the other includes the 220kV grid station and the power plants in the third phase. Auxiliary power for every plant in each group shall adopt a ring network connection by developing a circuit of 11kV line from two different power points to form a hand-in-hand power supply loop. During normal working, one point (such as point A) is to be selected to unlink. If there is a fault on any part of the power supply, the fault point should be removed and the switch of point A should be closed, which will guarantee power supply reliability to the maximum extent.

Plan for power supply system is shown in drawing No. 7.

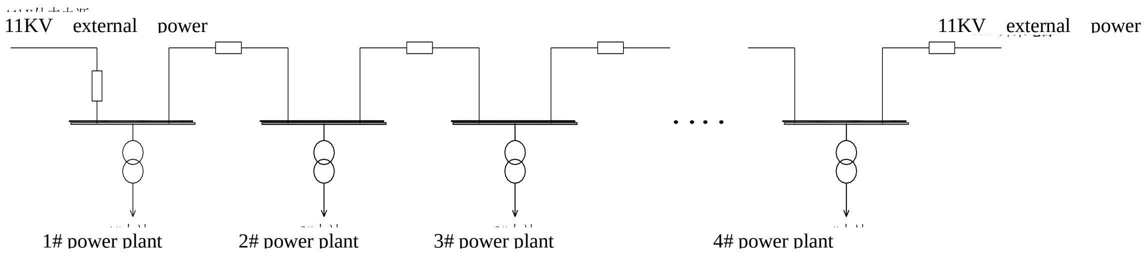


Fig. 3.5 Standby Power Supply Connection Method of the Park

3.6.3 Cable channels

This photovoltaic solar park has large installed capacity and would require a large number of cables, so cable galleries will be provided on the sides of main corridors in the park which will be used as cable connection channels for each power plant and step-up station.

Despite large volume of civil construction, the cable channels can accommodate a large number of cables and will be convenient for cable laying, maintenance and replacement. Each power plant and step-up station is proposed to be established as close to the main corridors as possible. Besides 33kV power cables, part of secondary cables will also be laid in the cable gallery.

3.7 TELECOMMUNICATIONS

For communication, data and image transmission and other requirements of the solar park the facilities of Pakistan Telecommunication Corporation Ltd. are proposed. A comprehensive telephone exchange will be provided in the park. Telecommunication cables shall be connected from the nearest urban center form a reticular system.

3.8 GENERAL SERVICES AREA

Just after the enterance to the QA Solar Park a vast area of 156 acres has been earmarked as general services area which is shown in drawing No. 2.

This area is reserved for the buildings and facilities for common services required for the whole QA Solar Park.

Offices of the QA Solar Park (Pvt.) Limited are proposed to be located in this area along with relevant facilities, like vehicle parking resthouse, living quarters for security and O & M staff, recreation partk, restaurant, convenience store etc. the water storage tanks and pumps house will also be located within this area for supply of water to the solar farms.

Each developer is expected to reserve some area within his solar farm for parking vehicles, loading – unloading facilities, control rooms, offices etc. however, for facilitating the first developer of the 100MWp solar farm a warehouse, some office facilities etc. are proposed to be provided in this area as well.

Chapter 4

ENVIRONMENTAL PROTECTION PROGRAM

4.1 PLANNING OBJECTIVES

Planning and construction of Photovoltaic Power Generation Park has to be similar to that of urban development, energy development and electric power generation. It has to be strongly supported by the Government and the line departments. While planning and preliminary evaluation of environmental impacts of the solar park, regulatory requirements have been kept in view and necessary measures have been proposed for construction of the Photovoltaic Solar Power Generation Park from the standpoint of environmental protection to effectively control and minimize the adverse impacts during construction and operation management and so as to make the Solar Energy (Renewable and Clean Energy) Power Generation Park and the surrounding ecological environment remain in harmony in order to ultimately promote the development of local economy and social uplift.

4.2 INVESTIGATION AND ASSESSMENT OF PRESENT ENVIRONMENT QUALITY OF THE PARK

4.2.1 Present water environment

The area is arid and water scarce. Two irrigation channels flow in the vicinity of the project area; Ahmadpur East Branch canal to the north and Desert Branch Canal to the east.

4.2.2 Present situation of atmospheric environment

Located on the edge desert, the project area is dry, dusty and windy. As the area is sparsely populated and without any industrial units, it is still pollution free so far. Atmospheric environment around the site can be conidered to be in Grade II or above, as per *Ambient Air Quality Standard* (GB3095-1996). It is further noted that Pakistan Environment Protection Agency (Pak-EPA) has so far no regulation for solar power generation in their Schedule I or Schedule II (PEPA Regulations 2000) so no environmental category can be allocated to this project at this juncture. Anyhow, thermal power generation is the closest energy generation reference which may be quoted for solar energy generation, according to which this project needs an EIA

4.2.3 Present situation of ecological environment

The site of the park is located in Cholistan desert, with only some wild vegetation growing sparsely, ecosystem is fragile; Due to low rainfall and other reasons, the site is mostly windy and dry and its soil loss is mainly due to wind erosion. No protected wild plants and animals are reported in the site.

4.2.4 Investigation and Assessment of Present Acoustic Environment Quality

The solar park site is not very close to the main roads of Bahawalpur district and noise is generated only by scanty local traffic plying on dirt roadsThe interior of the project area is unutilized land with some small settlements. As such present acoustic environment is good.

4.3 PRELIMINARY ASSESSMENT OF ENVIRONMENTAL IMPACT

4.3.1 Environmental rationality of site selected

Photovoltaic solar power generation project has the benefit of clean and renewable energy sources and is strongly supported by the government. Site selected is not limited by environmental constraints and complies with the policies regarding land utilization, new energy development, etc.

4.3.2 Identification of environmental impact factors

It is anticipated that excavation, compaction and other disturbances during construction are likely to loosen the earth, which may cause blowing of sand and dust and may result in some water and soil loss.

Impact of the on the environment during construction and operating period shall include domestic wastewater and garbage as well as construction waste.

4.3.3 Preliminary Assessment of Main Environmental Impact before Start of Construction

Before formal mobilization of the contractors, it will be necessary to relocate the residents present in the project area who will have to be offered reasonable cash or land compensation as per government regulations (Land Acquisition Act, 1894).

On the same footprint, trees and shrubs will have be removed to make the project area suitable for construction activities. Physical structures like residential houses, religious buildings, tube wells etc. will also need to be relocated before the start of construction activities.

4.3.4 Preliminary Assessment of Main Environmental Influence during Construction Period

1) Analysis of impact on environment by noise

During construction period, noise level will increase due to movement of construction machinery and equipment including bulldozers, trucks, excavators, concrete mixers, vibrators and generators, etc. Noise level of construction machinery is expected to be mostly be around 80dB-120dB. According to the construction experience on other construction projects, the above-mentioned noises shall have impact only on the construction site and the surrounding areas within 250m. This solar power park is located far away from the cites and major villages to cause any disturbance to the lives of residents.

Apart from that, commuting construction related vehicles will also add some noise to the surroundings of the construction site as well as the connecting routes with Bahawalpur.

2) Impact on air quality during construction period

Solar power generation itself shall not produce any toxic and harmful exhaust pollutants. However, the vehicular exhaust and dust blowing from the ground may have certain impact on local atmospheric environment. Dust blowing is mainly produced by excavation for engineering construction of solar panel foundations of box-type transformer, access roads, inverter room and production building, etc., loading and unloading of powdered construction materials (such as cement, lime), free stockpiling of powdered construction materials, and temporary stockpiling of earthwork and traveling of vehicles on the road, etc.

Quantity of blowing dust mainly depends on wind speed and dry or wet status of the ground surface. If construction is performed in summer, when wind speed is high and the surface is dry, amount of blowing dust would be great, which shall pollute air environment around the power plant especially in the wind direction. If construction is performed in spring when wind speed is low, the blowing dust is a less and shall have relatively less influence on air quality.

It is also envisaged that air quality will not be adversely affected by the solar power generation in operation phase. The pollution caused by dust blowing during construction is temporary and local. It will disappear after the completion of construction.

3) Impact on Environment by Waste Water and Sewage during Construction

The project will hardly produce any waste water except that produced temporarily by the labour camps. Water is mainly used for concrete mix, and hardly any waste water is produced. Domestic sewage produced by on-site constructors in their daily life is the main source of waste water, and the main contaminators of the sewage are BOD5, COD, and SS etc.

If domestic sewage is discharged without handling, it would pollute the environment. Therefore, it is forbidden for constructors to discharge sewage freely. When the sewage reaches standard through centralized processing unit, sludge should be collected and transported to some outside area frequently. Hence, the impact on environment by waste water and sewage during construction is not so serious.

4) Analysis of Impact on Environment by Solid Waste during Construction Period

The solid wastes during construction are mainly the construction spoil and the domestic garbage of the contractors, which is a temporary activity, and will come to an end as soon as the Project is completed and put into operation. So if during construction, the contractors handle construction waste safely and in a timely manner, the wastes will not have any impact on the environment. In addition, some of the construction materials can be recycled and the other can be disposed of properly outside the project area by trucks.

Besides as the number of labour would be large at the site, great deal of household garbage would be produced, including waste and old plastic bags, leftovers, waste packing materials, spoiled edibles etc. To prevent negative impact on the public hygiene and public health, such household garbage should be collected transported outside the park for safe disposal.

5) Impact on the Health of the Labour

The impacts on the health of the labour would occur mainly during the construction period. The infrastructures during the construction are relatively simple and crude. If the management measures are unfavorable for dietetic hygiene, drinking water and environmental sanitation, it may increase the probability of the spread of some infectious diseases.

6) Impacts on Ecological Environment

The zone is located at the edge of desert where the ecological environment is relatively fragile and vegetation is not rich. As such, there will be minimum damage to the ecological environment due to construction work.

7) Climatic Impact on the Project

The project site lies in an area with relatively high temperature in the summers. In general, adverse climatic impact will be produced on the project during the construction period, but it will not be so great because construction time is relatively short.

4.3.5 Preliminary Assessment of Environmental Impact during Operational Period

1) Atmosphere and Water Environment

Photovoltaic power generation converts solar energy to electric energy and no exhaust is given off during the converting process. In photovoltaic power generation, major water source is not needed during the production of electric energy except for washing of the solar panels and domestic usage. The amount of waste water so generated during the operating period in the project would be as most of the washing wastewater will be absorbed by the sandy terrain. The domestic waste can be transported outside after collecting in soakage pits or by transporting outside the project area. Thus, adverse impact on local water environment will not be great.

2) Ecological environment

The project area is almost a desert. No animals and plants under state protection are present in it, except that a small area on the edge is a forest, which is to be retained as it is.

Hence, the operation of the power plant will not change the local animals and plants, and thus will not produce any significant impact on the local ecological environment.

3) Light Pollution

At present, surface light reflection of Solar panel is relatively high, i.e. above 95%. The angle of reflected light from solar panel is not big, therefore, it may not disturb the drivers to face any flashing sensation.

4) Electromagnetic Radiation

The equipment operation in photovoltaic power plant will not have electromagnetism impact on nearby communication, radio or television signals.

5) Acoustic Environment

Photovoltaic power generation has no mechanical transmission mechanism or moving components, so no noise is produced during operational period. The motor vehicles running on highway will generate noise, but that will not affect the project area being far away.

6) Impact of Severe Weather

During gales and sand storms in the desert, there may be deterioration in the air quality, i.e., some reduction in visibility, atmospheric transparency and solar radiation accordingly. Therefore, severe weather will impose certain adverse impact on the generating capacity of photovoltaic power plant. Impact of sand must be considered in designing the PV plant and regular washing should be done to prevent abrasion.

4.3.6 Preliminary Analysis of Vegetation Impact During Operational Period

The construction of solar power plant has positive impact on the recovery of vegetation in the project area due to following reasons:

- Although the large scale arrangement of solar cell panels may block direct sunshine to some extent, large spaces between the lines of photovoltaic arrays can still bask in the sunshine at various times of the day. Meanwhile photovoltaic arrays absorb most of the solar energy, thus reducing the evaporation capacity of the earth surface.

- Regular washing of solar cell panels soaks the earth surface at regular intervals. Owing to rainwater and sunshine, vegetations grows easily on the ground.

- After the construction of photovoltaic power plant, boundary wall or fence will not allow grazing animals or people to enter and will thus protect vegetation. This phenomenon will therefore provide favorable conditions for recovery of vegetation.

- Grand flora (desert vegetation) having lower height than panels are expected to grow significantly, also called afforestation, because they will revive regular supply of water which is released after washing solar panels.

4.4 MEASURES AGAINST ADVERSE ENVIRONMENTAL IMPACTS

4.4.1 General

According to the environmental protection principles, 4 inch top soil of construction area may be excavated before construction and it will be relocated again below the panels to restore the site.

4.4.2 Environment protection measures

1) Ecological Environment Protection Countermeasures

In order to preserve the ecological environment during construction, the construction operations should be arranged in accordance with the environment management system requirements to shorten the construction period, and reduce the environmental impacts on surrounding landforms. Following ecological protection measures should be adopted for the project:

A. The construction operations should be contained within the land acquired for the solar park in order to reduce the damage to surrounding land. The approach road and the temporary roads for movement of construction equipment should be properly planned, and no land acquisition should not be acquired for construction roads. The existing earthen roads should be used during construction as far as possible to reduce the land damage and avoiding additional land acquisition.

B. The power generation and electrical equipment should be placed at the positions specified in design plan, and the construction machines and the equipment should not be piled without approval to control the floor space and protect the original landform.

C. Preference should be given to environment-friendly equipment for construction, and construction operations should be planned to minimize dust and noise emissions, It should be guaranteed that any effluent discharges meet the environmental standards and guidelines.

D. The top-soil should be intensively piled and protected, and after the construction, the exposed land surface should be re-covered with the original top-soil.

E. The use of large machines should be minimized during the construction. After excavation, the foundation trenches should be concreted as soon as possible and backfilled in time. The surface layer of the trench should be ground to minimize the exposure time and reduce the dust emission. Blasting should be forbidden for excavation of foundation trenches so as to reduce the impact of dust and vibration on the surrounding environment.

F. After construction, the cable ducts should be backfilled in time, with the original landform recovered.

2) Prevention of Exhaust Gas and Dust Pollution

Ecological protection and soil conservation measures should be adopted so that secondary dust and exhaust gases are not generated during construction.

The exhaust gases will generally be discharged during the operation of motor-driven vehicles including transport vehicles and construction machinery (bulldozers, mixers, and cranes etc.). Since the proposed site for the Project is open and with better ventilation condition, the exhaust discharged by the vehicles can be diffused rapidly and it will not have great impact on the atmospheric environment in local areas. However, the number of construction vehicles should be controlled to minimize the impact on atmospheric environment.

The dust blowing during construction is mainly generated from the stockpiling of powered materials, the temporary piling of earth and the vehicle transportation. In order to reduce the impact of dust blowing during construction on the atmospheric environment, the following control measures should be taken into account:

A. The construction personnel should regularly spray water at the construction site to prevent the generation of suspended dust. The volume and frequency for water spraying should be increased when the wind is strong and weather is dry.

B. The construction personnel should clean and spray water at the transportation roads to reduce the dust blowing generated by vehicle movement.

C. After entering the construction site, the transport vehicles should run at a low speed or at a limited speed to reduce dust emission.

D. Covered trucks should be used to deliver the materials that cause dust emission like slags and cement.

E. The materials that easily cause to dust emission should be covered after they are piled.

F. The concrete batching plant should be set within the enclosed construction camp.

G. All the dusty materials transported in and out the construction site should be covered by tarpaulins.

H. The pre-mixed concrete and precast cement products should be used as far as possible rather than dry cement.

I. Light-absorption system shall be compatible with the requirement of photovoltaic solar power plants because gales and storms would occur periodically in Cholistan.

J. Cholistan has a long history of facing extreme temperatures during summers, up to 50°C. In the PV design, the climatic impact on solar cell modules and electrical equipment should be taken into consideration. It is required to ensure that the module and equipment can be properly operated.

By taking the above measures, it is envisaged that dust emission can be effectively controlled at the construction site. In the same way Dust emission outside the construction boundary is successfully kept at the level lesser than 1.0 mg/m^3.

3) Noise Pollution Mitigation Measures

No noise would be generated during the operation of the power plant; however noise generation cannot be avoided during the construction period. In order to minimize the noise impacts on surrounding areas, the contractor(s) should carry out the personal protection guidelines during construction period, e.g. OSHA guidelines.

A. The owner should ensure the use of low noise, and low vibration construction equipment and corresponding technologies used by the contractor as the key points of bidding.

B. The construction contractor should designate relevant personnel to conduct regular maintenance and servicing for construction equipment, and take charge of performing training for field personnel so as to ensure each personnel can operate various machines according to the operation specifications strictly and reduce the noise produced due to the improper maintenance of construction machinery.

C. Construction work should be carried out during day time as far as possible and the construction period should be as short as possible also.

D. The construction area is relatively far away from the sensitive targets of the acoustic environment. So impact of construction noise on the surrounding environment will be negligible. However the requirements of *Noise Limits for Construction Site* (GBl2523-90) should be ensured by taking the above-mentioned measures.

4) Sewage and Waste Water Treatment Measures

The production of wastewater from the Project construction activities is mainly generated by washing the concrete truck mixers and other construction machinery, repairing equipment and maintaining vehicles, but the total amount of such waste water is small. The construction sites are relatively scattered, and the scope is also relatively wide, so the waste water can be used for spraying at the construction site. During the construction period, the sewage should be collected, and the domestic sewage should be transported outside for safe disposal.

During normal operation of the power plant, the administrative staffs are mainly engaged in handling official business, monitoring and overhauling, so the waste water is mainly the domestic sewage. The domestic sewage should be collected and regularly transported outside for safe disposal.

5) Solid Waste Disposal and Public Health Measures

The handling of earth excavated during construction: During excavation, the top-soil and bottom soil should be properly stock-piled separately at specified locations. After the construction, the exposed area should be covered with bottom soil first, and then with the top-soil;

- After the excavation and backfill, the left-over waste can be used as the filling material for the low-lying areas, if needed. After the backfill, these areas should be compacted and planted to avoid water and soil loss, vegetation growth and protect the environment;

- In addition, some of the construction waste excavation can be recycled the remaining can be transported together with the domestic waste to some nearby landfill through a truck.

- Each power plant should be equipped with centralized solid waste collecting boxes which should be cleaned regularly. The solid wastes generated during the construction operation should be transported outside the park to avoid spreading out due to wind blowing and effluent leakage from polluting the surrounding.

- During the normal operation of the power plant, the administrative staffs are mainly engaged in handling official business, monitoring and overhauling, and the solid wastes are mainly the office and domestic wastes. The living area should be provided with dust bins to collect the wastes, and the collected wastes should be transported to the nearby specified landfill site.

- Meanwhile, proper management of dietetic hygiene, domestic drinking water and environmental sanitation should be ensured to prevent the spread of infectious diseases and to protect the population health.

- A central disposal center for the wasted material of photovoltaic modules, transformer elements and cables should be located in the service area of the Park. When the quantity of this waste reaches certain number, the waste should be uniformly sorted. The recyclable photovoltaic modules should be broken up and sent to relevant factories for recycling as required, while other parts that are hard to be recycled should be disposed of according to relevant regulations.

4.4.3 Foundation Selection for Photovoltaic Power plant

The selected foundation type in design of the photovoltaic power plant has a great effect on protection of the park's environment. Currently, the foundation types of photovoltaic power generation project adopted mainly include reinforced concrete independent foundation, reinforced concrete strip foundation, and pile foundation etc.

The type of foundation depends on topography and involve relatively modest requirements regarding the construction level and quality of the construction team, simple processes and moderate construction cost. However, the natural earth surface will be disturbed due to some earthwork and considerable dust will be raised . If the mechanical excavation is used, more earth surface will be disturbed and damaged.

If the site area is flat, strip foundation can be placed on the ground directly. In this case earthwork and the damage of vegetation will be less, and the construction schedule will be rapid. But it requires flat land, which is available only in a small part of the project area.

If the topography is undulating, mechanical excavation for strip foundation would cause greater surface disturbance and damage than that of the independent foundation. Compared with the cast-in-situ independent foundation, the strip foundation will require larger quantity of concrete and shall appear to be bulkier.

The pile foundation generally uses the static pressure for driving precast piles or use cast-in-situ bored pile construction process. Among several kinds of foundation types, the pile foundation has minimum earthwork, formwork quantities complexity, and earth surface damage. Construction is rapid by mechanical drilling. The pile foundation generally involves reinforced concrete precast pile, reinforced concrete cast-in-situ bored pile, and spiral steel pile etc.

According to the geological condition of site, all solar farm entrepreneurs are required to adopt foundations which cause minimum surface disturbance and damage during the photovoltaic power plant construction. It is recommended to use cast-in-situ bored pile or any type of foundation which requires lesser surface disturbance and earthwork. The remaining excavated material should be protected effectively and the exposure of silty soil should be controlled to reduce the damage to the vegetation.

4.5 COMPREHENSIVE EVALUATION AND CONCLUSIONS

4.5.1 Beneficial Effects

The power supply generated by the solar energy is a clean and renewable energy source. The construction of the solar power plants in the QA solar park is in line with the national energy development policies. It can become a major source of power supply to the national power grid. Compared with the coal-fired power plants, a solar power plant discharges much less atmospheric pollutants and wastes, thus improving the quality of atmospheric environment. In addition, the solar power plant becomes the local scenic spot for scientific education and tourism, which shall be beneficial to promote the development of the local tourism industry. Meanwhile, it shall also bring along development of the local tertiary industry to improve the local economic development. Therefore, the development of QA solar park will not only reap better economic benefits, but will also deliver obvious social and environmental benefits.

4.5.2 Adverse Effects

Solar power plant utilizes clean energy, and there is no negative impact, nor does it cause any pollution to the environment. The adverse effects to the environment appear mainly during the construction period, which can be minimized by taking effective measures.

4.5.3 Conclusions and Suggestions

To summarize, the construction of QA solar park has no major environmental problems which may discourage the project construction as the project will not restrict the sustainable use of local environmental resources and natural cycle of ecological environment. Only if proper and effective environmental protection measures are taken, the adverse effects generated by the project construction to the environment will be controlled properly.

Due to too many construction units entering the park, although the effects of the power plant to the ambient environment can be controlled and protected by taking some reliable protective measures, the supervising strength shall be enhanced to ensure the proper implementation of various effective measures.

It is recommended that the Proponent should obtain an environmental approval from the Punjab-EPA before proceeding further into the construction activities.

Chapter 5

FIRE PROTECTION ENGINEERING PLANNING

5.1 PRINCIPLES

The fire protection planning for the park conforms to the policies of the Government of Pakistan while following the principles of "Prevention First, Extinguishment Combined with Prevention". Fire protection facilities in the Park will be provided according to the current fire protection regulations issued by the Pakistan Government. Based on the characteristics of the solar park, common fire stations and fire control facilities shall be provided keeping in view the risk level of fire hazard so that fire-fighting facilities are available near the likely flammable sources. Effort should however be made to reduce the possibility of fire, by conflagration and minimizing flammable sources. In case of fire, the facilities provided should be utilized in an efficient manner, in order to suppress it and avoid fatalities and property damage.

5.2 FIRE FIGHTING ACCESS

Latticed roads shall be constructed in the solar park, with width of more than 4m. The access road to the solar park off-takes from the Bahawalpur-Hasilpur Road, through which fire-fighting trucks can conveniently access the area of a fire in the park.

5.3 FIRE STATION AND RELEVANT SUPPORTING FACILITIES

The QA solar park is about 18km away from Bahawalpur, where a fire station is available. This fire station can meet the fire protection requirements of the park. As such there is no need to build a dedicated fire station within the park itself.

5.4 FIRE WATER SUPPLY AND FIRE WATER QUANTITY

The water for fire-fighting is proposed to be supplied through the main water supply pipe running between the eastern and western corridors.

According to relevant specifications of the *Design Code on Building Fire Protection and Prevention* (GB50016-2006), if an industrial park area is more than 1km^2, it is to be assumed that fire is likely to break out at two places simultaneously.

Keeping in view the features of photovoltaic power generation park and the relevant specifications of *Code of Design on Building Fire Protection and Prevention* (GB50016-2006), the water consumption for one fire extinguishing event is 20L/s, and the duration of fire for one event is assumed to be 2h. Accordingly, the fire water requirement for simultaneous fires at two locations comes to 288m^3.The fire water is proposed to be stored at the clean-water reservoir of the proposed water pumping station in the general services area, and the clean-water reservoir shall not be used for fire. Two sets of fire pumps will be provided; one at the water supply pump station in general services area, and the other outside the 220kVA step-up station to pump the water from the clean-water reservoir. The clean-water reservoir shall be provided with an intake for filling the tanks of fire fighting trucks.

5.5 SETUP OF OUTDOOR FIRE HYDRANT

According to the features of the solar power generation park, and on the basis of the relevant specifications of *Code of Design on Building Fire*

Protection and Prevention (GB50016-2006), fire hydrants will be provided in the general services area and the 220 kVA step-up station. The outdoor fire hydrant shall be erected along the roadside, and the arranged distance between the hydrants shall be no more than 120 mm.

5.6 FIRE POWER SUPPLY

The fire devices shall be designed according to the secondary load power supply standard, using double circuit power supply and switching automatically at the end. The fire devices shall use fire protection or fire-resistant cables.

5.7 FIRE PROTECTION FACILITY FOR EACH SOLAR FARMPLOT

The fire protection and fighting system of each plot in the park shall be designed and provided by each solar farm entrepreneur himself as a part of safety requirement .

Chapter 6

DEVELOPMENT SEQUENCE AND CONSTRUCTION PHASING

6.1 DEVELOPMENT SEQUENCE OF SOLAR FARMS

Keeping in view the external factors (such as development of solar grid generation technology, regional power system development plan, Pakistan Government's policies on solar power generation) and site-related factors (such as landform, transportation, construction, installation, and system connection) sequential development of various solar farms in the park is envisaged. Accordingly Phase-I of this photovoltaic solar park is proposed to have a generation capacity of 100MW, while Phase-II will add another 300MW. Finally in Phase III 600MW solar farms will be developed to make a total of 1,000MW.

6.2 INFRASTRUCTURE DEVELOPMENT

Infrastructure construction should proceed in parallel to the schedule of solar energy development in order to achieve the overall plan objective to facilitate expeditious completion of photovoltaic solar power plants in all the three phases. Infrastructure construction, involving the general services area, power evacuation facilities, roads, and water supply pipelines should be completed in various sections to ensure availability of necessary facilities in advance of the start of work on the proposed solar farms progressively. It is important to realize that this park is expected to be a model park of solar power generation in Punjab and even in Pakistan. Its success depends first on the development level of infrastructure. It is therefore necessary to provide infrastructure of high quality in time to facilitate rapid development of solar farms for providing 1000 MW additional power to the Pakistani nation at the earliest to alleviate their tribulations caused by persistent power shortages.

1) Development items for Phase I

As GoPunjab intends to develop 100 MW solar farm on priority basis with its own funds, it is important that adequate infrastructure facilities should be in place and be functional at the time the pre-construction work starts for Phase-I to ensure early implementation and timely commissioning of the 100MW solar farm. The immediate requirement of infrastructure will essentially include the approach road to the solar park area, internal road within the eastern corridor of the project area up to the gate of the 100MW solar farm**,** boundary walls for safety of the priority area, 11kV line for temporary electricity connection and water supply arrangement. Temporary office and residential buildings using pre-cast units are also proposed in the southern portion of the service area, adjacent to the 100MW solar farm.

Power evacuation system to connect the farm with the 132 kV transmission line should be in place before testing and commission stage of Phase-I of the solar farm.

2) Development items for Phase II

In this phase additional solar farms will be added to generate 300MW. The power generated by all these farms is to be evacuated through the existing 132 kV transmission line passing through the eastern corridor around which these farms are to be developed.

For this purpose, all infrastructure facilities will have to be completed early in the eastern part of the project. Infrastructure construction, including the main road, water supply lines, overhead power supply lines and boundary wall extension should proceed in parallel with, but ahead of the awarding of contracts to various entrepreneurs. Infrastructure work should proceed from north to south and should be completed before awarding the southern most farms to solar development firms.

3) Infrastructure Development items for Phase III

In Phase III, 600 MW power will be evacuated through the new 132 kV power lines which is to be laid in the western corridor on both sides on which these solar farms are to be built. It is recommended that Infrastructure development work for Phase-III area should start in parallel with the development of Phase-I and Phase-II so that the infra-structure is available before the work on Phase-III of the solar power generation starts.

Infrastructure works for this phase include all main roads, 132 kV transmission lines for power evacuation, 220kV step-up station which is to be built by NTDC and the final section of the boundary wall.

Chapter 7

ESTIMATE OF INVESTMENT AND ECONOMIC BENEFIT

7.1 ESTIMATE OF INVESTMENT

7.1.1 Estimate of Power Generation Facility

For a 50MWp power plant (poly-silicon fixed type) investment per kilowatt for a Photovoltaic power plant is about US$ 2,131/ kWp as per the market price of main equipment and materials of photovoltaic power generation system. Accordingly, it is estimated that the total investment for power generation facilities of all power plants will be US$ 2,131 million .

7.1.2 Estimate of Infrastructure Facilities

The infrastructure in Quaid-E-Azam Solar Park, mainly includes the roads, water supply and sewerage works, electricity supply, communication facilities and erosion & torrent control works. As per the development sequences already planned, this Project is divided into Phase I, Phase II and Phase III respectively for preparing preliminary cost.

The preliminary cost estimate has been prepared as per the price level of the second quarter in 2013, which is shown in table 7.1.

The total investment of the infrastructure facilities is US$ 250 million out of investment for Phase-I will be US$ 16.748 million while for Phase II and Phase III, it will be US$ 34.31 million and US$ 198.94 million.

7.1.3 Exclusions

1) This estimate excludes the land cost.

2) The solar farm developers will step-up the power to 132 kV before connection in to the 132 kV lines in the main corridor.

3) The cost of 220kV step-up station is not included.

4) Costs of environmental protection and water & soil conservation and arrangement of labor safety and industrial hygiene are not covered .

7.1.4 Total Investment Estimate

Table 7.1 Total Investment Estimate

Unit: US$ 31x10^{6} (millions)

No.	Name of Engineering or Costs	Phase I	Phase II	Phase III	Total
I	**Public facilities in the Park Zone**	8.71	23.8	150.5	183.00
1	Road & access works	0.862	1.82	3.34	6.02
2	Water supply and drainage works	0.736	0.22	0.567	1.52
3	Electrical works	6.96	21.5	146.23	175.00
4	Communicative works	0.157	0.888	0.348	0.792
II	**Comprehensive service zone**	2.48	0	0	2.48
III	**Environmental protection, water and soil conservation works**	0.155	0.252	1.46	1.86
IV	**Labor safety and industrial hygiene works**	0.052	0.084	0.486	0.621
V	**Other costs**	3.16	5.70	20.56	29.42
1	Construction unit management fee	1.47	2.71	7.92	12.10
2	Production preparatory expense	0.185	0.30	1.11	1.59
3	Scientific investigation and design expense	0.586	1.20	6.96	8.75
4	Miscellaneous taxes and dues	0.92	1.49	4.57	6.98
VI	**Basic reserve fund**	2.19	4.48	25.95	32.60
VII	**Total static investment**	16.7	34.3	198.9	250.00

7.2 ECONOMIC BENEFITS

7.2.1 Energy Consumption

In the near future, Pakistan's Quaid-E-Azam Solar Park will have a total installed capacity of 1,000 MW. As per poly-silicon stationary estimation, its annual average power generation would stand at 12.7 billion kW/h after completion. Compared to thermal power of the same capacity, it can save upto 407,200t of coal each year. It can be indicated that the utilization of solar energy can play a major role in improving energy structures and saving energy resources, which can significantly reduce coal consumption and make up for the lack of fossil resource reservation.

7.2.2 Ecological Environmental Benefits

The exploitation and utilization of solar energy can be used as an alternative to fossil fuels that would reduce the emission of greenhouse gases into the atmosphere and would contribute in preserving the environment. After the completion of Pakistan's Quaid-e-Azam Solar Park, about 4,560.95t of sulfur dioxide emissions, 4,707.55t of nitrogen oxide emissions, 5,509.79 t of soot emissions, 1.225 million t of carbon dioxide emissions, and 10.71 million t of carbon monoxide emissions would be reduced each year.

7.2.3 Social Benefits

The photovoltaic Park construction and its maintenance can create a lot of job opportunities and also promote the development of industries relating to solar energy. The construction of the photovoltaic park can speed up the development of new power projects in Pakistan to ensure a steady supply of power for Pakistan's economic growth.

7.2.3 Economic benefits

1) Power generation benefits

The installed capacity of the Solar Park will be 1,000MWp and the average annual generating capacity is estimated to be 12.7 billion kW·h.It brings about a great deal of benefit for the power sector and also contributes towards the revenue of Pakistan.

2) Investment benefits

When the construction of the Park is completed, the total investment in the Park would reaches about 14,525 million Yuan (among which, the total investment of the power generation parts of all power plants reaches 13 billion Yuan, while the one of public facilities parts accounts for 1,525 million Yuan).

The scale merit of the construction of the Park is very transparent. Proper planning, short construction cycle and high efficiency, has saved investment and benefited all investors who have participated in the development and construction of the Park.

In brief, the development and construction of the Park can cater to the domestic power demand, can be economically beneficial, promote and coordinate development of regional economy and optimize the local economic structure. Additionally, the investment, construction and operation of the Park would contribute to the local finance, improve the overall living standard of the regional people, improve the local infrastructure conditions, speed up the development of the related industries and create more employment opportunities.

Chapter 8

SUPPORT MEASURES

8.1 ESTABLISHMENT OF A CONTINUOUS AND STABLE MARKET SYSTEM

Formulate policies to promote solar energy development according to photovoltaic generation principles, alongwith government guidance and support that will attract investors and will create a photovoltaic market that shall have a stable growth. In order to achieve this, a strong regulation system on solar power development, intellectual properties, technology transfer, and technology diffusion is to be formed to ensure realization of planned objectives in the photovoltaic generation park.

Development objectives must be practical to promote sequential and rapid development of the solar park. Guidance on the development and construction should be received by preparing divisional and sub item feasibility study report based on the resource conditions, development conditions, economic development conditions, and industrial policies.

8.2 ESTABLISHMENT OF A CONTINUOUS AND STABLE MARKET SYSTEM

Expand investment channels and establish a funding system for solar energy utilization involving the government’s support as the guide, enterprises as the principal part, and bank loan as the support. Increase photovoltaic generation investment in a multi-channel, multilevel, and diversified way. Strive for support of photovoltaic generation investment projects from financial institutions for enterprises and local governments; guide financial institutions to complete financial service and strengthen credit aid to photovoltaic generation. Establish development fund for solar power generation to provide fund for the photovoltaic generation park by fully utilizing capital market funding and attracting investment.

8.3 COMPLETION OF SYSTEM SERVICES AND UTILIZATION EFFICIENCY IMPROVEMENT

With government and enterprise support, establish a technical system, management system, and service system for Pakistani photovoltaic generation park. Standardize maintenance and management of solar equipment. Dopt a benign development cycle in the park by reducing operation cost, improving equipment utilization rate, and extending equipment service life.

8.4 GRID SUPPORT MEASURES

The electric power department should adopt safety mesures to ensure that the output power generated from the photovoltaic power stations are tolerated by the grid without any influence on the safety of the grid operation.

Chapter 9

CONCLUSION AND SUGGESTION

9.1 CONCLUSION

1) With strong sunlight, lack of overcast, long sunshine duration, averageing at 3201 h yearly, high radiation intensity, averaging at 6,408MJ/m^2 yearly in Bahawalpur District, the solar resources are very rich.

2) The development scale of Phase I of the Solar Park is 100MW, 300MW in Phase II and 600MW in Phase III. At that time the total development scale will reach 1000MW.

3) After the completion of the Park, the total investment will reach RMB 14.525 billion Yuan, including RMB 13 billion Yuan for the generation facilities of all plants and RMB 1525 million Yuan for the infrastructure (RMB 102 million for Phase I, 209 million for Phase II, and RMB 1214 million Yuan for Phase III).

4) After the Solar Park is completed, sulfur dioxide emissions are likely to be reduced by 4,560.95t, nitric oxide emissions by 4,707.55t, smoke emission by 5,509.79t, carbon dioxide emission by 1.225 million t and carbon monoxide emission by 1.071 million t.

9.2 SUGGESTION

1) A unified plan, construction, and management organization should be established to coordinate with the development and

utilization. Besides, municipal infrastructure construction should be completed as soon as possible to provide availability of roads, water, and power in the Park.

2) For this Project, a monographic study on influence of access system of the solar Park station on the grid as well as a monographic study on generating capacity forecast and power quality should be conducted as soon as possible to provide technical support and service to the large-scale grid-connected photovoltaic generation station.

3) Conduct actual measurement of solar energy resource at the park site in order to provide basic date for the next work.

4) Strengthen the contact with the power company so that the criteria of the Solar Park complies with that of the power system.

5) Strive for Pakistani preferential development policies on the Solar Park construction and necessary economic incentive measures of the government.

6) Enhance government departments' support on the preliminary works of the photovoltaic station, and summarize the amount of cost for preliminary works.

7) A monographic study of the influence of the park construction on the environment should be conducted as soon as possible, and protective measures should be taken.

---END-----------------------------------